

# **Seasonal and Day-to-Day Variations in PM Mass and Chemical Components**

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## 1 INTRODUCTION

The San Joaquin Valley, Sacramento Valley, San Francisco Bay Area, and Mountain Counties Air Basins exhibit strong seasonal patterns in particulate matter concentrations, with highest concentrations measured in fall and winter.

In this section, we examine variations in seasonal patterns from year-to-year and site-to-site using three data sets:

- 1) Historic data – This data set is based on multiple years (1990-2000).  $PM_{2.5}$  data were collected using dichotomous (dichot) samplers, while  $PM_{10}$  data were collected using size-selective inlet (SSI) federal reference method (FRM) samplers. Data were collected on a one-in-six day schedule, except for key  $PM_{10}$  sites, which operated on a one-in-three day schedule during the high seasons (fall and winter).
- 2) CRPAQS data – This is the most comprehensive data set in terms of spatial and temporal coverage and includes both routine and CRPAQS data collected between December 1, 1999 and February 18, 2001. During months when concentrations are generally high, key sites measured  $PM_{2.5}$  concentrations everyday and  $PM_{10}$  concentrations once every three days.
- 3) Routine data – These data were collected at the ongoing backbone monitoring network which includes SSI samplers for  $PM_{10}$  and FRM samplers for  $PM_{2.5}$ . Compared to the CRPAQS data set, it includes less frequent sampling for  $PM_{10}$  and fewer sites and less frequent sampling for  $PM_{2.5}$ .

The following questions are considered:

- 1) How well did the data collected during CRPAQS reflect the long-term seasonal pattern exhibited by historic data?
- 2) Did the better spatial and temporal coverage of the CRPAQS network result in higher concentrations than the routine networks? If so, can we attribute the differences to better spatial or temporal coverage, both, or neither?

## 2 DATA COLLECTION

### 2.1 $PM_{2.5}$

Between 1990 and 2000,  $PM_{2.5}$  concentrations were measured in the San Joaquin Valley, San Francisco Bay Area, and Sacramento Valley using dichotomous samplers. The dichotomous (dichot) sampler uses a low-volume  $PM_{10}$  inlet followed by a virtual impactor that separates particles into the  $PM_{2.5}$  and  $PM$  coarse fractions. Generally, dichot samplers operated on a one-in-six day schedule. Table 2-1 includes the number of dichot samples collected at each site from 1990 to 2000. Monitoring sites in this table, as well as all other tables in this document, are sorted first by an air basin and then by latitude, from north to south.

**Table 2-1 Count of PM<sub>2.5</sub> historic dichot measurements per year.**

Basin	Site Name	Year										
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
SJV	Stockton-Hazelton St.	62	55	41	60	60	48	61	59	59	58	62
SJV	Modesto-I St.	41	58	61	60	62	60	60	80	69		
SJV	Modesto-14th St.									40	112	118
SJV	Madera-Library	39	49	59	60	62	59	46				
SJV	Fresno-1st St.	42	60	56	60	55	63	62	57	55	55	60
SJV	Visalia-N Church St.	54	53	58	61	60	46	61	59	60	59	10
SJV	Corcoran-Patterson Ave.							5	60	58	60	13
SJV	Corcoran-Van Dorsten Ave.	48	40	27	61	60	50	59	58	45		
SJV	Bakersfield-Chester St.	57	55	55	55	15						
SJV	Bakersfield-5558 California Ave.					36	50	75	112	109	100	117
SJV	Taft College	8	56	49	57	49	58	61	47	40	53	8
SFB	San Jose-4th St.	56	58	59	61	61	61	54	57	55	55	10
SV	Sacramento-T St.		27	66	73	80	78	78	67	54	55	59

Beginning in 1998-1999, PM<sub>2.5</sub> Federal Reference Method (FRM) samplers, also referred to as routine samplers, were deployed at urban monitoring sites throughout California to support national ambient air quality standards for PM<sub>2.5</sub>. At the two key sites in the San Joaquin Valley, Bakersfield-California and Fresno-1<sup>st</sup>, routine samplers operate on a daily schedule. The remaining sites operate on a one-in-six day schedule from April through September and on a one-in-three day schedule from October through March. After the network of routine samplers was established, the dichot samplers were phased out.

The CRPAQS network of PM<sub>2.5</sub> mass monitors included all of the routine sites and some additional sites deployed as part of CRPAQS. The sampling frequency at CRPAQS sites was adjusted based on the expected concentrations. During a projected episode many of the CRPAQS sites operated on a daily basis. Table 2-2 lists routine and CRPAQS monitoring sites in the San Joaquin Valley, Sacramento Valley, and San Francisco Bay Area Air Basins.

**Table 2-2 PM<sub>2.5</sub> routine and CRPAQS monitoring sites.**

Basin	Site Name	Site ID
SJV	Agricultural fields/Helm-Central Fresno County	HELM
SJV	ANGIOLA	ANGI
SJV	BAC Residential	BRES
SJV	Bakersfield-410 E Planz Road	BSE
SJV	Bakersfield-5558 California Avenue	BAC
SJV	Bakersfield-Golden State Highway	BGS
SJV	Clovis-N Villa Avenue	CLO
SJV	Corcoran-Patterson Avenue	COP
SJV	Edison	EDI
SJV	Feedlot or Dairy	FEDL
SJV	Fellows	FEL
SJV	Foothills above Fellows	FELF
SJV	Fresno MV	FREM
SJV	Fresno-1st Street	FSF
SJV	Fresno-Hamilton & Winery	FSE
SJV	Kettleman City	KCW
SJV	Merced-2334 M Street	MRM
SJV	Modesto-14th Street	M14
SJV	Oildale-3311 Manor Street	OLD
SJV	Pacheco Pass	PAC1
SJV	Pixley Wildlife Refuge	PIXL
SJV	Residential area near FRS, with woodburning	FRES
SJV	Selma(south Fresno area gradient site)	SELM
SJV	Sierra Nevada Foothills	SNFH
SJV	Stockton-Hazelton Street	SOH
SJV	SW Chowchilla	SWC
SJV	Taft College	TAC
SJV	Tehachapi Pass	TEH2
SJV	Visalia-N Church Street	VCS
SV	Chico-Manzanita Avenue	CHM
SV	Colusa-Sunrise Blvd	CSS
SV	Pleasant Grove (north of Sacramento)	PLE
SV	Redding-Health Dept Roof	RDG
SV	Roseville-N Sunrise Blvd	ROS
SV	Sacramento-Del Paso Manor	SDP
SV	Sacramento-Health Dept Stockton Blvd	SST
SV	Sacramento-T Street	S13
SV	Woodland-Gibson Road	WLN
SV	Yuba City-Almond Street	YAS

Table 2-2 (continued)

SFB	Altamont Pass	ALT1
SFB	Bethel Island	BTI
SFB	Bodega Marine Lab	BODG
SFB	Concord-2975 Treat Blvd	CCD
SFB	Fremont-Chapel Way	FCW
SFB	Livermore-793 Rincon Avenue	LVR1
SFB	Redwood City	RED
SFB	San Francisco-Arkansas Street	SFA
SFB	San Jose-4th Street	SJ4
SFB	San Jose-Tully Road	SJT
SFB	Santa Rosa-5th Street	SRF
SFB	Vallejo-304 Tuolumne Street	VJO

## 2.2 PM<sub>10</sub>

The PM<sub>10</sub> FRM network of SSI samplers has been operating in California since 1984. Table 2-3, Table 2-4, and Table 2-5 include the number of PM<sub>10</sub> samples collected at each monitoring site between 1990 and 2001 in the San Joaquin Valley, Sacramento Valley, and San Francisco Bay Area Air Basins, respectively. While no additional sites were deployed as part of CRPAQS, several sites increased sampling frequency to every third day.

**Table 2-3 Count of PM<sub>10</sub> historic measurements per year in the San Joaquin Valley Air Basin.**

SITE_NAME	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Stockton-Wagner-Holt School							13	58	58	41	59	57
Stockton-Hazelton Street	63	53	53	58	59	49	60	60	58	60	61	63
Modesto-Oakdale Road	18											
Modesto-14th Street							22		40	119	120	67
Modesto-I Street	61	60	62	61	61	61	62	85	72			
Westley-Truck Stop	46	20										
Turlock-S Minaret Street				46	61	61	61	59	61	54	60	61
Crows Landing-Davis	61	20										
Merced-2334 M Street										44	60	56
Merced-Health Dept	60	59	57	60	60	60	46					
Los Banos-5th Street	60	57	55	60								
Madera-Library	57	60	54	60	61	60	43					
Clovis-N Villa Avenue		43	56	59	60	60	61	60	59	58	55	57
Fresno-Cal State #2	12											
Fresno-1st Street	45	58	55	61	37	64	63	61	60	60	61	61
Fresno-Olive Street	3											
Fresno-Drummond Street	59	53	55	61	59	61	61	61	58	53	56	56
Porterville-Courthouse	51	29										
Five Points	56	26	11	60								
Visalia-N Church Street	58	52	47	60	61	63	61	61	62	61	61	59
Hanford	53	56	57	38								
Hanford-S Irwin Street				9	55	59	62	60	52	54	51	58
Corcoran-Patterson Avenue							15	59	65	117	97	81
Corcoran-Van Dorsten Avenue	57	51	55	59	59	65	64	63	46			
Kettleman City-CalTrans	55	56	58	60	60	60	63					
Kern Refuge	60	39	50	53								
Oildale-3311 Manor Street	63	60	59	61	62	68	63	58	60	56	63	63
Bakersfield-Golden State Highway					26	61	60	56	40	59	61	53
Bakersfield-5055 California Street			44									
Bakersfield-Chester Street	60	54	59	71	17							
Bakersfield-5558 California Avenue					52	88	78	120	116	115	115	78
Taft College	24	59	59	57	54	61	59	59	54	64	65	42
Taft-N 10th Street	3											

**Table 2-4 Count of PM<sub>10</sub> historic measurements per year in the Sacramento Valley Air Basin.**

SITE_NAME	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Burney-Siskiyou	46	55	41	13								
Redding-Health Dept Roof	52	58	55	59	59	58	46	56	57	54	60	58
Anderson-North Street				29	50	60	60	58	60	34	61	61
Red Bluff-Riverside Drive	60	60	61	60	56	49	48	55	50	44	59	53
Chico-Manzanita Avenue			40	73	69	73	67	63	60	60	71	60
Paradise-Fire Station #1												53
Chico-Salem Street	73	72	30									
Willows-N Villa Avenue	71	72	71	74	28							
Willows-E Laurel Street					40	68	61	61	56	58	61	59
Biggs-9th and C Street	8											
Smartville-CDF	59	26										
Colusa-Sunrise Blvd	73	61	70	65	64	71	59	62	59	55	60	58
Yuba City-Almond Street	71	69	71	73	62	68	65	63	60	57	65	59
Auburn-Dewitt-C Avenue						9	47	49				
Lincoln-L Street						10	55	53				
Rocklin-Sierra College	54	24										
Rocklin-Rocklin Road		2	41	73	71	74	60	63	59	60	73	61
Roseville-N Sunrise Blvd				69	71	74	68	62	61	60	71	61
Sacramento-Earhart Drive				35	58	52	49	49				
North Highlands-Blackfoot Way				39	57	59	59	59	61	56	59	54
Citrus Heights-Sunrise Blvd	66	56	65	13								
Woodland-Sutter Street			42	55	50	54	58	59	61	5		
Woodland-West Main Street	59	26										
Woodland-Gibson Road									12	59	60	58
Sacramento-3801 Airport Road									35	58	52	42
Sacramento-Del Paso Manor				46	59	58	50	56	59	58	61	51
West Sacramento-15th Street	19	44	58	59	58	58	59	60	59	59	58	61
Sacramento-T Street	26	69	71	97	79	82	77	63	61	60	70	58
Sacramento-Health Dept Stockton Blvd				44	59	60	51	60	60	56	50	34
Sacramento-Branch Center Road				39	61	60	60	51	59	54	59	43
Vacaville-Merchant Street	41	43	58	58	58	58	60	61	59	59	61	61

**Table 2-5 Count of PM<sub>10</sub> historic measurements per year in the San Francisco Bay Area Air Basin.**

Site Name	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Santa Rosa-5th Street					31	61	61	61	61	59	60	61
Napa-Jefferson Avenue	61	60	61	61	59	61	61	60	60	60	61	61
Vallejo-304 Tuolumne Street					9	61	61	61	61	60	61	61
Pittsburg-10th Street										25	61	61
Bethel Island Road	61	60	61	61	60	61	61	61	61	60	61	61
San Rafael	61	60	61	61	61	61	61	61	61	60	61	61
San Pablo-El Portal								40	30			
Richmond-13th Street	61	59	61	61	61	60	61	21				
Concord-2975 Treat Blvd	62	60	61	59	60	61	61	61	61	60	61	61
San Francisco-Arkansas Street	61	60	61	61	61	61	61	61	61	60	61	61
San Leandro-County Hospital	26	60	61	61	61	61	61	61	30			
Livermore-Old 1st Street	61	60	61	61	55	61	61	61	61	60	61	
Livermore-793 Rincon Avenue										3	62	61
Fremont-Chapel Way	61	59	61	61	61	61	61	61	61	60	61	61
Redwood City	61	60	61	61	61	61	61	61	61	60	61	61
San Jose-935 Piedmont Road						12	61	60	30			
San Jose-4th Street	178	170	61	27	55	61	61	61	60	60	61	61
San Jose-W San Carlos Street	60	60	61	61	61	15						
San Jose-Moorpark Avenue	61	60	61	61	61	61	61	61	30			
San Jose-Tully Road	61	60	61	61	61	61	61	61	61	60	60	61

### **3 DATA ANALYSIS**

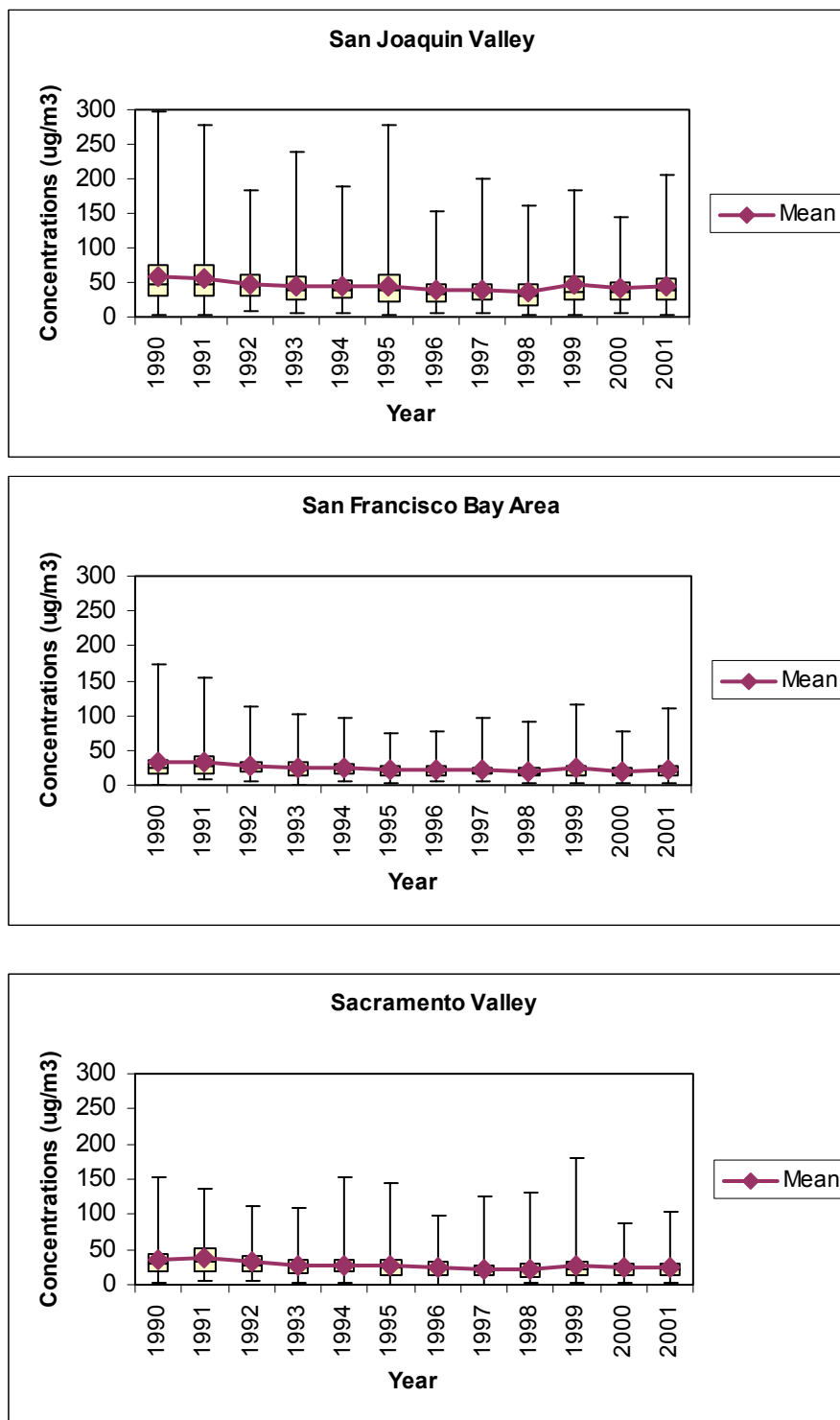
Box-and-whiskers plots are used to show minimum, maximum, median, mean, and lower and upper quartiles for a data series. The caps at the end of each box indicate the extreme values (minimum and maximum). The box is defined by the lower and upper quartiles. The line in the center of the box is the median. The median represents the middle value for an odd number of data points or the mean of the middle values for an even number of data points. The lower quartile represents the middle value between the median and the minimum data and the upper quartile represents the middle value between the median and the maximum data value. The diamond represents the mean concentration.

The variation in concentration was calculated as a standard deviation of the data over the mean of the data, expressed in percentages. To determine the overall variation within a month, the 1990-2000 data were first grouped by month. We then calculated monthly average concentration, standard deviation, and coefficient of variation. To determine the year-to-year variations, the same calculations were performed on data grouped by both month and year. The 1990-2000 average represents an average variation across all years. Site-to-site variations were calculated by grouping data by site and by month and calculating average, standard deviation, and coefficient of variation within each group.

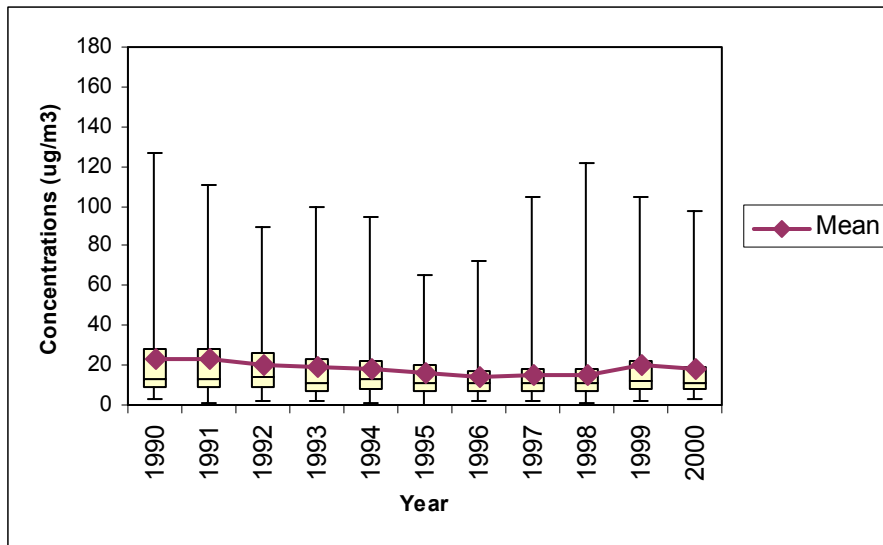
### **4 YEAR-TO-YEAR VARIATIONS**

PM concentrations in central California vary from year to year. In addition to emission reductions, weather can also be a cause of variations. For example, during El Nino years, such as 1997-1998, PM concentrations were low. Figure 4-1 and Figure 4-2 illustrate year-to-year variations in  $PM_{10}$  and  $PM_{2.5}$  concentrations, respectively.  $PM_{2.5}$  dichot monitoring was discontinued in 2000,  $PM_{2.5}$  FRM monitoring commenced in 1999, and 1999-2003 data is illustrated in Figure 4-1.

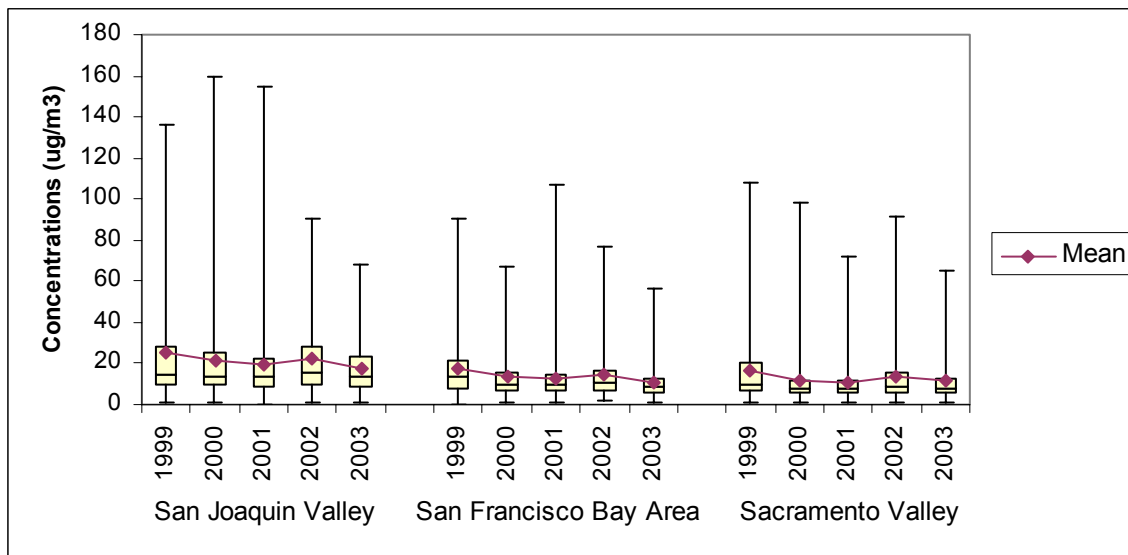
**Figure 4-1 PM<sub>10</sub> concentrations from 1990 through 2001.**



**Figure 4-2 PM<sub>2.5</sub> dichot concentrations in the San Joaquin Valley from 1990 through 2000.**



**Figure 4-3 PM<sub>2.5</sub> FRM concentrations in the Central California from 1999 through 2003.**



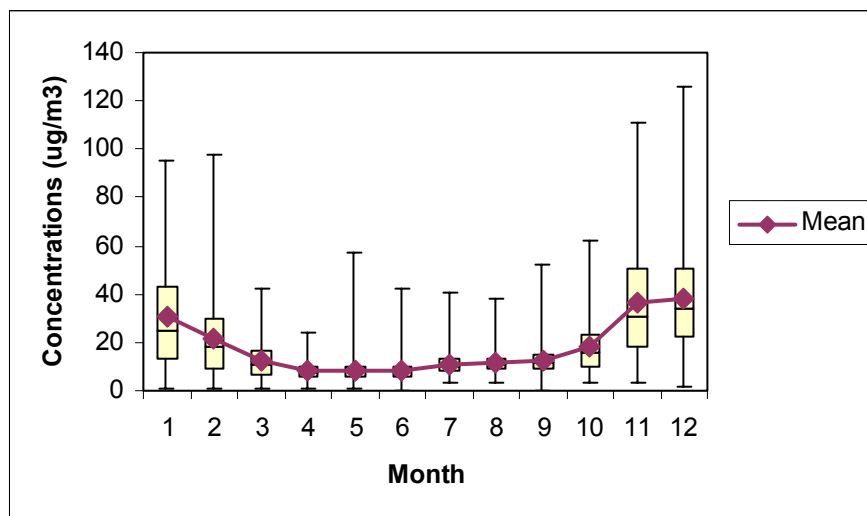
## 5 SEASONAL VARIATIONS

This section examines the seasonal patterns in  $PM_{2.5}$  and  $PM_{10}$  concentrations and their main chemical components. Statistical parameters were calculated for each month. The seasonal patterns for  $PM_{2.5}$  and  $PM_{10}$  were first examined using historical 1990 through 2000 dichot and SSI data, respectively. The historical patterns were then compared to the CRPAQS and routine data. The seasonal patterns in the main chemical components were examined using data collected between December 1, 1999 and February 18, 2001. The main chemical components described in this section are ammonium nitrate and carbonaceous aerosols for both  $PM_{2.5}$  and  $PM_{10}$ , as well as geological material for  $PM_{10}$ .

### 5.1 $PM_{2.5}$ Concentrations

Based on the dichot data collected in the San Joaquin Valley between 1990 and 2000, average and peak  $PM_{2.5}$  concentrations were highest during the following four months: January, February, November, and December. The seasonal pattern is shown in Figure 5-1.

**Figure 5-1 Monthly variations of  $PM_{2.5}$  dichot concentrations in the San Joaquin Valley from 1990 through 2000.**



There were, however, significant statistical variations between the four highest months, as shown in Table 5-1. December, with a 1990-2000 average concentration of  $39 \pm 24 \mu\text{g}/\text{m}^3$  and a peak concentration of  $126 \mu\text{g}/\text{m}^3$ , was the highest month. November, with an average concentration of  $36 \pm 23 \mu\text{g}/\text{m}^3$  and a peak of  $111 \mu\text{g}/\text{m}^3$ , was only slightly lower. January, the third highest month, had an average concentration of  $31 \pm 22 \mu\text{g}/\text{m}^3$  and a peak of  $102 \mu\text{g}/\text{m}^3$ . February was the lowest of the top four, with an average of  $22 \pm 17 \mu\text{g}/\text{m}^3$  and a peak of  $98 \mu\text{g}/\text{m}^3$ . December and November were not only the highest months but they had the least variation in concentrations across all years, 61% and 64% respectively. Concentrations were more variable during January and February, with a

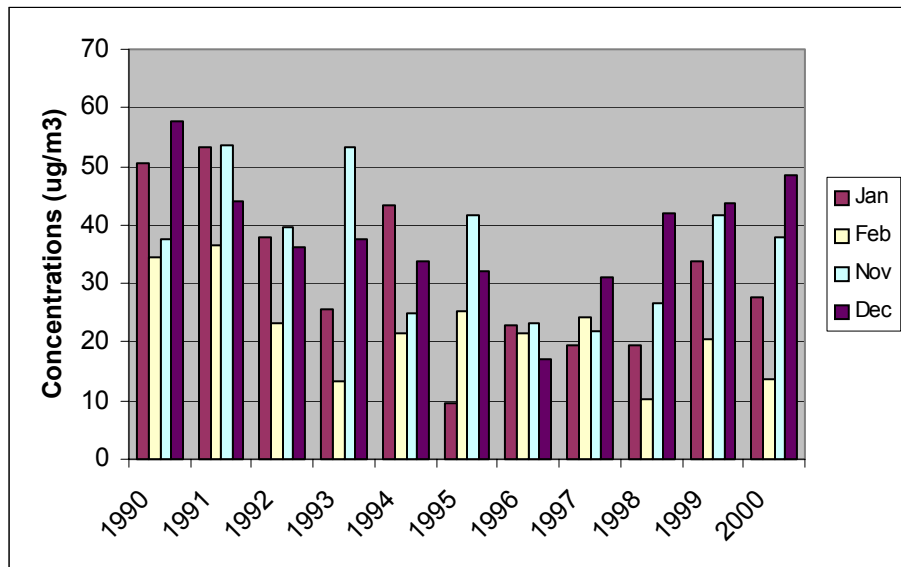
1990-2000 average variation of 71% and 79% respectively. The overall high variability during the winter months reflects the nature of the PM<sub>2.5</sub> problem. Concentrations are high when atmospheric conditions promote accumulation and formation of particulate matter. Favorable conditions include lack of precipitation, limited vertical mixing, and low winds. However, even during the winter months conditions are not always favorable. Rainy weather, or good vertical and horizontal mixing, is usually associated with low concentrations. Therefore, winter data includes a wide range of concentrations, from very low to extremely high. The site-to-site variations were greater than year-to-year variations, but not by much. This indicates that elevated concentrations do not affect the entire Valley to the same degree and a spatially representative network is critical for accurate assessment of the PM<sub>2.5</sub> problem.

**Table 5-1 Statistical summary of PM<sub>2.5</sub> dichot, 1990-2000.**

Month	PM <sub>2.5</sub> Concentrations (µg/m3)			Coefficient of Variation (%)					No in Avg
	1990-2000 Avg	Annual Low (Year)	Annual High (Year)	1990-2000 Avg	Year-to-Year		Site-to-Site		
					Avg	Range	Avg	Range	
Jan	31 ± 17	10 ± 7 (95)	53 ± 20 (91)	71	59	37-78	66	36-91	441
Feb	22 ± 15	10 ± 6 (98)	36 ± 26 (91)	79	66	52-74	72	35-110	395
Nov	37 ± 20	22 ± 9 (97)	54 ± 28 (91)	64	55	31-88	62	46-78	413
Dec	39 ± 24	17 ± 11 (96)	58 ± 29 (90)	61	53	35-76	58	37-81	428

Based on the data collected between 1990 and 2000, average PM<sub>2.5</sub> concentrations were highest in December, but this was not true for individual years. Any of the four highest months, except February, could be the peak month within a given year (Figure 5-2). During some of the early years, 1991-1993 and 1995-1996, November was the highest month. Later years, 1997, 1998, 1999, and 2000, had the highest concentrations in December.

**Figure 5-2 Year-to-year variations in PM<sub>2.5</sub> monthly average dichot concentrations.**



### 5.1.1 Comparison of CRPAQS PM<sub>2.5</sub> Data to Historic and Routine

The PM<sub>2.5</sub> data collected during CRPAQS exhibited the same seasonal variations as historic data, with highest concentrations during January, February, November, and December (Figure 5-3). While the overall pattern was similar, CRPAQS captured winter concentrations significantly higher than those measured during the past eleven years of dichot monitoring.

CRPAQS concentrations exceeded not only historic levels but also those levels measured in the routine network during the CRPAQS period (Figure 5-4). Better spatial and temporal coverage during CRPAQS, as described in more detail below, resulted in significantly higher concentrations compared to the routine network.

- 1) Spatial coverage – The difference in peak values between the CRPAQS and routine networks reflects the difference in monitoring purpose. The source-oriented monitoring sites deployed as part of CRPAQS were designed to capture the highest values while the population-oriented routine sites represented an overall exposure of populations that might be affected by elevated concentrations. The top seven values for January 2001, ranging from 159 to 179  $\mu\text{g}/\text{m}^3$ , were captured at CRPAQS sites. The highest was Edison with a PM<sub>2.5</sub> concentration of 179  $\mu\text{g}/\text{m}^3$  on January 5, 2001. Bakersfield-California, with a PM<sub>2.5</sub> concentration of 155  $\mu\text{g}/\text{m}^3$  also on January 5, 2001, was the highest routine site.
- 2) Temporal coverage – More frequent sampling and more complete data from the CRPAQS network resulted in capturing higher concentrations. The routine network missed peak days in early January, resulting in much lower concentrations. For example, the Fresno-1<sup>st</sup> site did not collect any routine data from January 1 through 7, the peak days for that month. Similarly, Bakersfield-California and other sites missed most, if not all, of the peak days.

The most significant deviation from historic levels occurred during January of 2000 and 2001. In 2000, the peak values exceeded the historic peak by 35  $\mu\text{g}/\text{m}^3$  at CRPAQS sites and by 58  $\mu\text{g}/\text{m}^3$  at routine sites (Figure 5-5), but average concentrations were fairly typical. January 2001, with a mean concentration two times greater than the historic average and a peak concentration over 70  $\mu\text{g}/\text{m}^3$  higher, was clearly the highest PM month during CRPAQS.

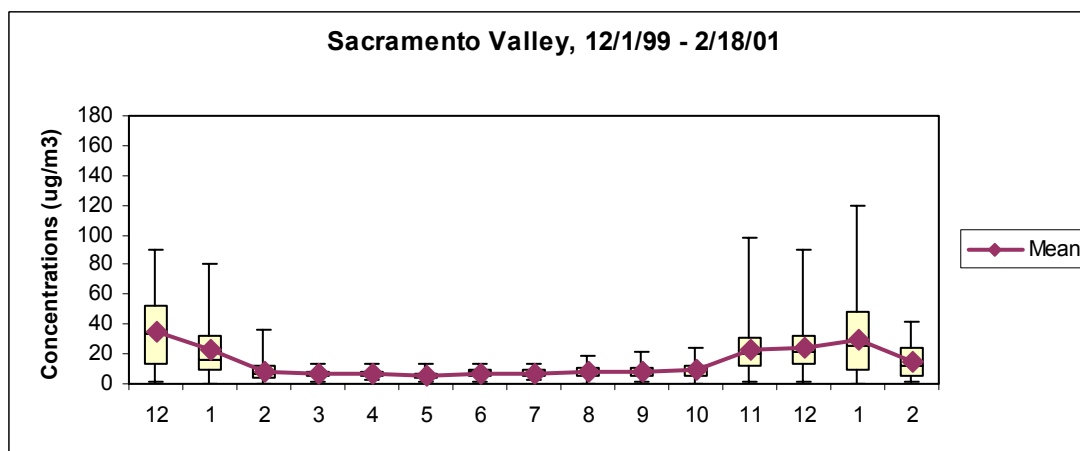
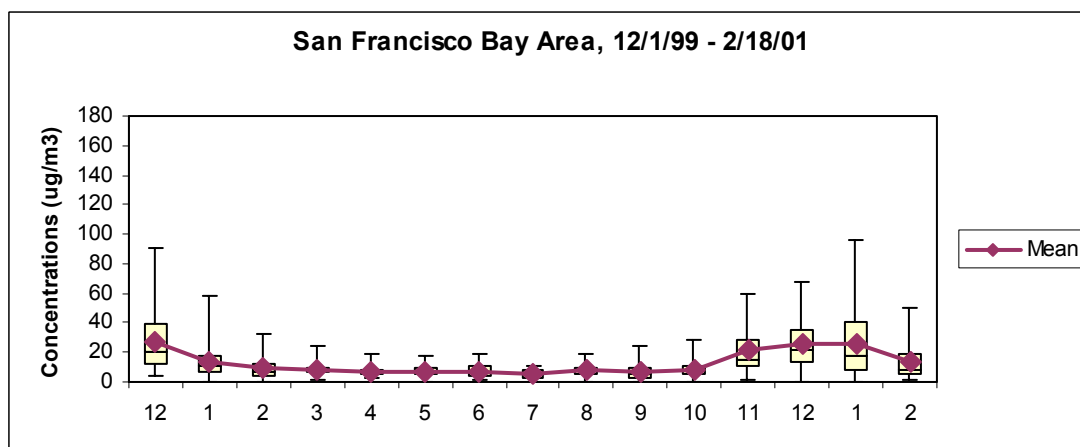
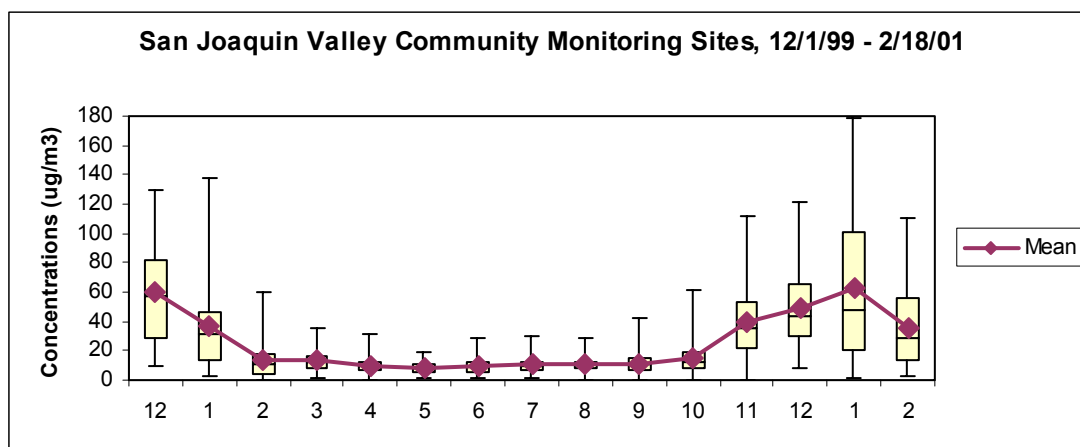
The third set of box-and-whiskers plots in Figure 5-5 compares the PM<sub>2.5</sub> data for January 2001. The first box-and-whiskers in this set is based on CRPAQS data, the second one is based on routine data, and the third is based on the CRPAQS network of sites but matched to the routine sampling days. The differences between the first and the third box reflect the influence of better temporal coverage while the differences between the second and the third box reflect impact of better spatial coverage. Better temporal coverage of CRPAQS network was much more important for accurately representing PM<sub>2.5</sub> concentrations than improved spatial coverage. The most complete data, represented by the first box, was on average 40% higher compared to the data in third box, which included all of the same sites but was missing measurements on some days. Boxes two and three were based on the

same sampling days, but box three included additional source-oriented CRPAQS sites and therefore had better spatial coverage. These additional sites had almost no impact on average concentrations but captured peak concentration about  $25 \mu\text{g}/\text{m}^3$  higher compared to the population-oriented routine sites in box 2. The significant impact of better temporal coverage emphasizes the importance of collecting complete data in order to accurately represent concentrations and make the most of the existing routine network.

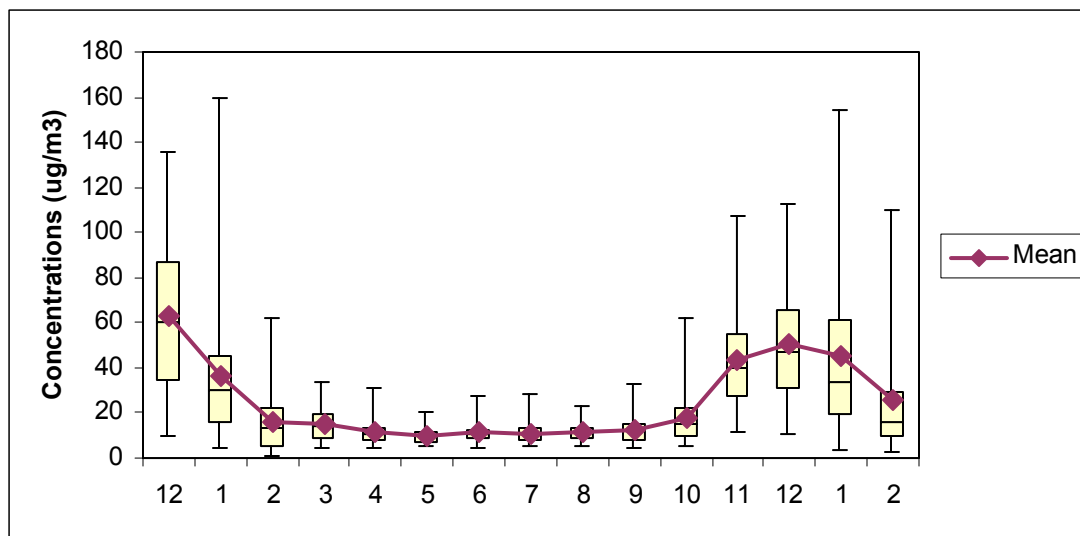
During February 2000, concentrations were lower than usual, but February 2001 was similar to historic levels (Figure 5-6). However, CRPAQS 2001 data were collected only during the first half of February and do not reflect a typical month. The routine data, which includes the entire month, closely resemble the multiyear levels. The November 2000 routine and CRPAQS data also closely mimicked historic levels (Figure 5-7). The December peak concentrations were also close to the historic peak, but the average concentration was higher by 40% in 1999 and by 30% in 2000 (Figure 5-8). The December CRPAQS and routine data were consistent for both years, 1999 and 2000, even though the CRPAQS network included more sites and more sampling days.

The deviations from historic levels do not necessarily mean that concentrations have never been as high before. Since the dichot network operated on a one-in-six day schedule, our ability to accurately assess PM levels was limited. A winter episode in the Valley can last more than two weeks. With a one-in-six days sampling, we might capture one or two episode days but not necessarily the peak days. Daily sampling, at least at key sites, greatly improved our ability to accurately assess PM levels. This is especially important during the high months. When the concentrations are not very high, as was the case in February and November, even one-in-six days sampling provided a good estimate of the PM levels. Better filter handling procedures of routine samples, which reduce the loss of PM<sub>2.5</sub> mass due to nitrate volatilization, might be another reason why routine concentrations are higher than dichot during winter months. .

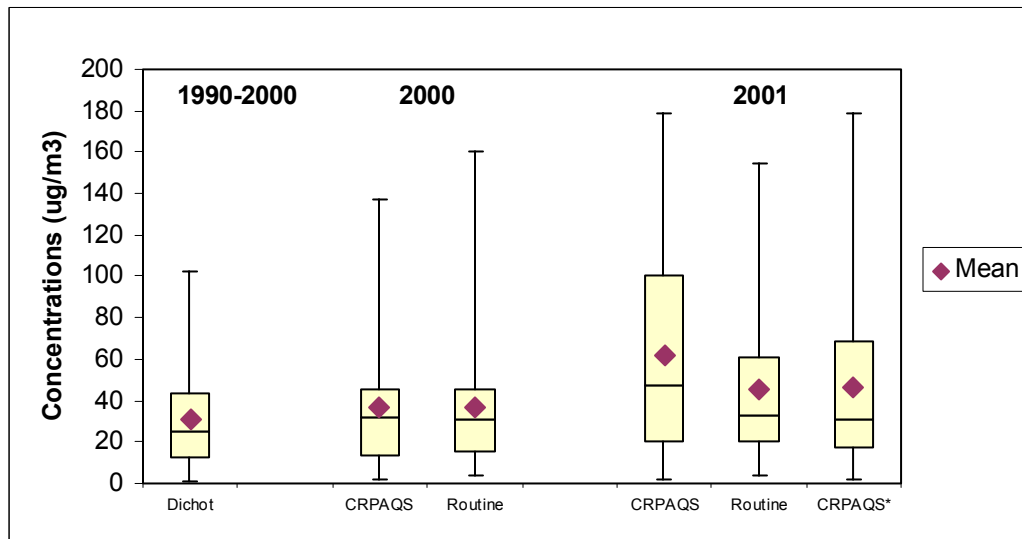
**Figure 5-3 Box-and-whiskers plot of PM<sub>2.5</sub> concentrations collected at CRPAQS monitoring sites between 12/1/99 and 2/18/01.**



**Figure 5-4 Box-and-whiskers plot of PM<sub>2.5</sub> concentrations collected at FRM routine monitoring sites between 12/1/99 and 2/28/01.**

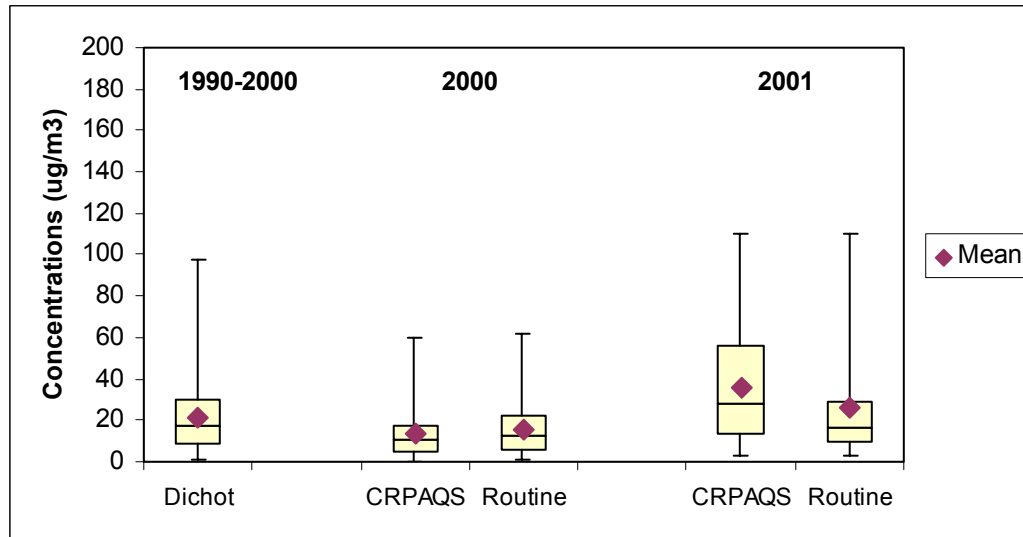


**Figure 5-5 Comparison of PM<sub>2.5</sub> concentrations for January.**

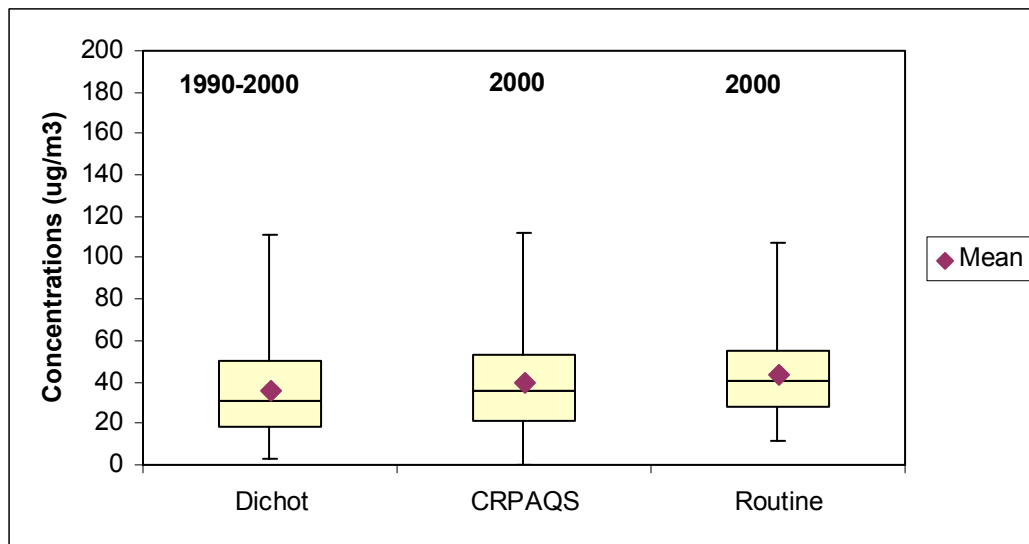


CRPAQS\* - Data from CRPAQS network matched to routine based on the sampling day.

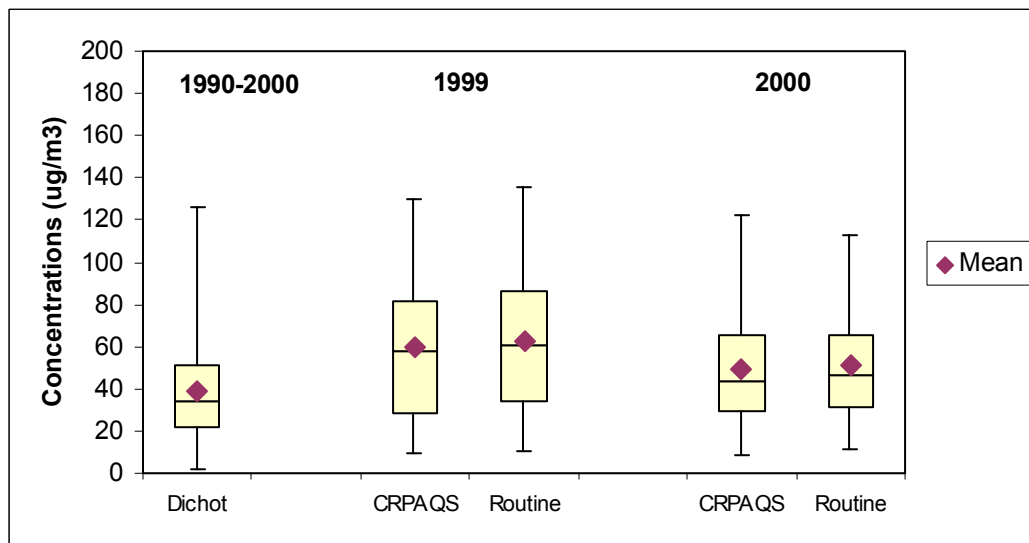
**Figure 5-6 Comparison of PM<sub>2.5</sub> concentrations for February.**



**Figure 5-7 Comparison of PM<sub>2.5</sub> concentrations for November.**



**Figure 5-8 Comparison of PM<sub>2.5</sub> concentrations for December.**



## 5.2 PM<sub>10</sub> Concentrations

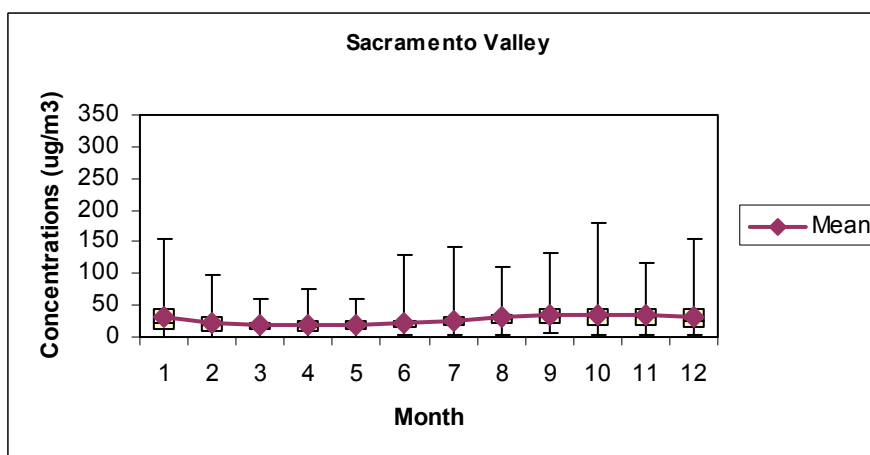
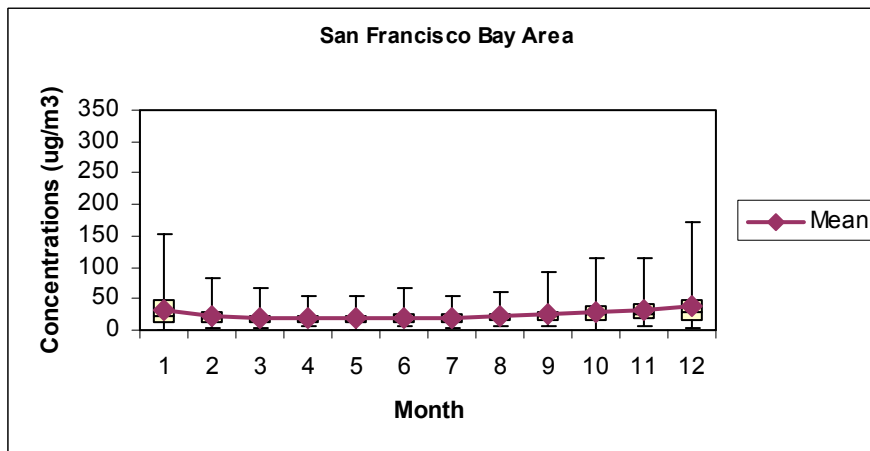
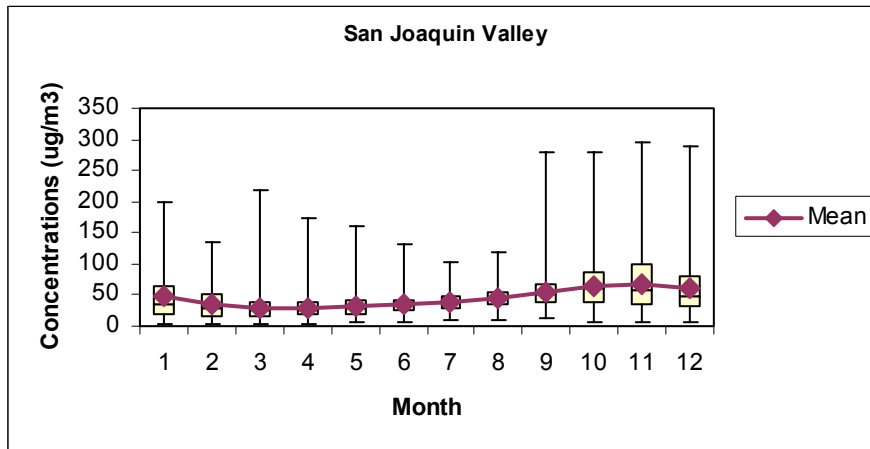
PM<sub>10</sub> exhibits a slightly different seasonal pattern than PM<sub>2.5</sub>. The differences are related to the fact that PM<sub>10</sub> include both PM<sub>2.5</sub> particles, as well as particles in the 2.5 to 10 micron range that are predominately composed of geological material. This geological material has a different seasonal pattern than fine particle constituents. Based on the 1990-2000 data, PM<sub>10</sub> concentrations were highest during fall and winter. The high season includes January and September through December. This pattern is shown in Figure 5-9. All three air basins, the San Joaquin Valley, the San Francisco Bay Area, and the Sacramento Valley have a similar seasonal pattern, but the San Joaquin Valley has highest concentrations and most pronounced pattern.

During the high season, concentrations still exhibited significant month-to-month variations. Table 5-2 compares statistical parameters for the highest PM<sub>10</sub> months in the San Joaquin Valley. November, with a 1990-2000 average concentration of  $68 \pm 42 \mu\text{g}/\text{m}^3$  was the highest month. October, with an average concentration of  $65 \pm 34 \mu\text{g}/\text{m}^3$ , was only slightly lower. The next highest was December (average concentration of  $60 \pm 41 \mu\text{g}/\text{m}^3$ ), followed by September (average concentration of  $55 \pm 24 \mu\text{g}/\text{m}^3$ ). January with an average concentration of  $47 \pm 35 \mu\text{g}/\text{m}^3$  was the lowest of the five months. Concentrations were less variable in fall compared to winter. During fall the coefficient of variation ranged from 44% in September to 60% in November. Variation was significantly greater during winter months, from 70% in December to 76% in January. Similar to PM<sub>2.5</sub>, site-to-site variations were slightly greater than year-to-year variations indicating that spatial differences between sites are significant, supporting the need for a spatially representative network.

**Table 5-2 Statistical summary of PM<sub>10</sub> SSI, 1990-2000.**

Month	PM <sub>10</sub> Concentrations (µg/m3)			Coefficient of Variation (%)					No in Avg
	1990-2000 Avg	Annual Low (Year)	Annual High (Year)	1990-2000 Avg	Year-to-Year		Site-to-Site		
					Avg	Range	Avg	Range	
Jan	47 ± 35	20 ± 11 (95)	81 ± 43 (91)	76	60	39-80	67	35-89	935
Sep	55 ± 24	38 ± 12 (97)	72 ± 38 (91)	44	38	25-53	39	17-72	890
Oct	65 ± 34	45 ± 23 (00)	93 ± 37 (91)	51	46	36-60	46	14-61	902
Nov	68 ± 42	43 ± 28 (94)	99 ± 50 (93)	60	55	29-89	58	40-81	880
Dec	60 ± 41	23 ± 12 (96)	101 ± 66 (90)	70	53	40-74	66	44-102	932

**Figure 5-9 Historical PM<sub>10</sub> concentrations from 1990 through 2000.**



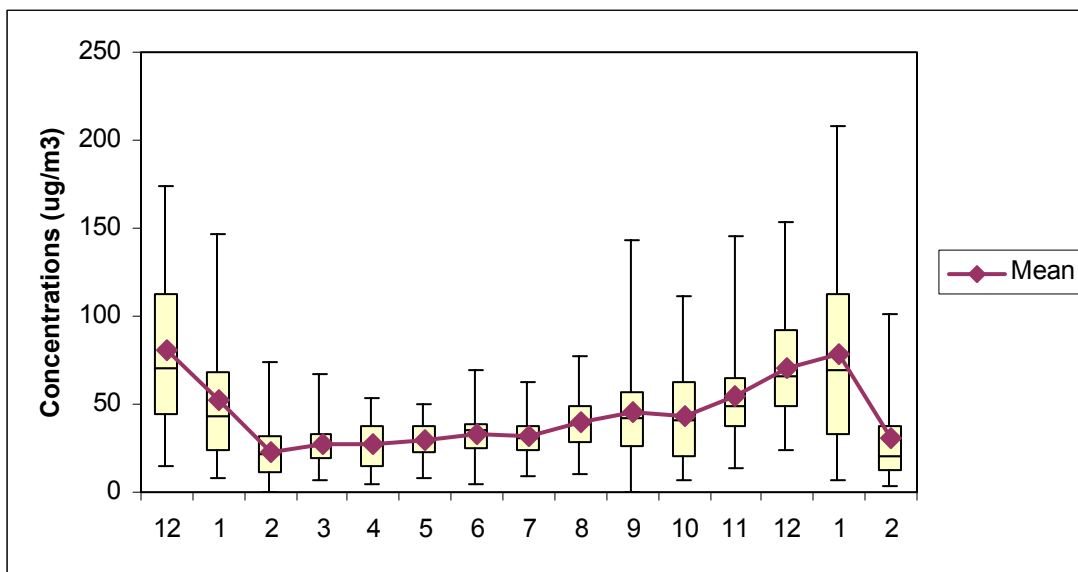
### 5.2.1 Comparison of CRPAQS PM<sub>10</sub> Data to Historic and Routine

The CRPAQS study included a 15-month period, from December 1999 through early February of 2001. Figure 5-10 shows PM<sub>10</sub> concentrations during this period. Historically high PM<sub>10</sub> concentrations traditionally experienced during the fall (September through November) did not occur during CRPAQS (Figure 5-11). On the other hand, the winter months (January and December) were higher during CRPAQS than during previous years (Figure 5-12).

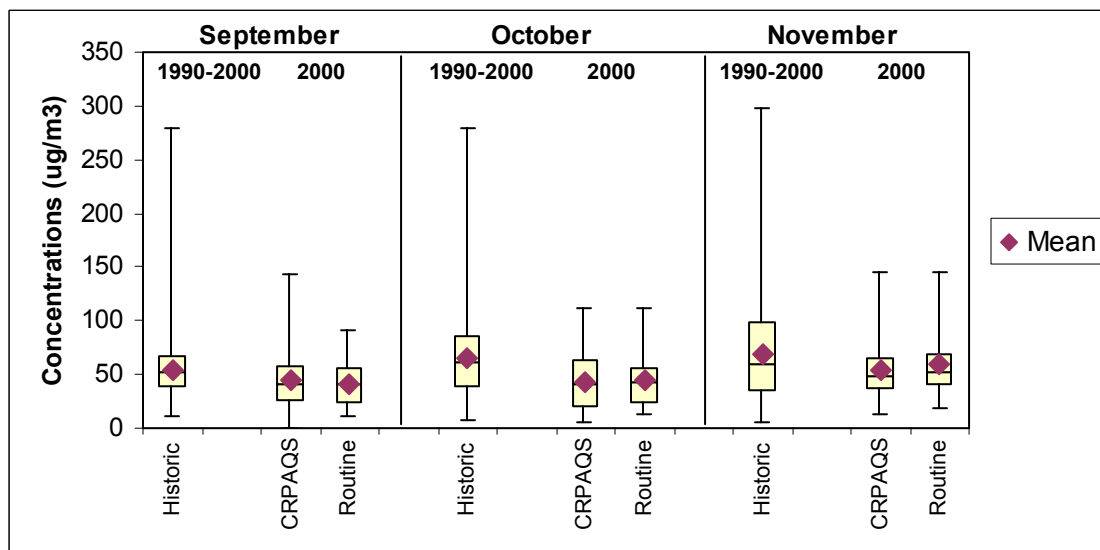
Fall PM<sub>10</sub> concentrations (September, October, and November) measured during CRPAQS were significantly lower compared to historic data. Average concentrations (including mean, median, and 25<sup>th</sup> and 75<sup>th</sup> percentiles) were 10 µg/m<sup>3</sup> to 20 µg/m<sup>3</sup> lower and the peak concentrations were 50 to 60% lower than historic concentrations. Fall CRPAQS and routine data were consistent except for September when, due to more frequent sampling, the CRPAQS network captured a high wind event that was missed by the routine sampling schedule. This single day event measured peak concentrations 50 µg/m<sup>3</sup> above those captured by the routine sampling schedule. The winter months with high PM<sub>10</sub> concentrations were January and December. The 15-month CRPAQS period included January of both 2000 and 2001. While January 2000 had only slightly higher averages and lower peak concentrations compared to historic data, January 2001 had average concentrations 60 to 80% higher and a peak value close to the historic data maximum. The CRPAQS study also included December of 1999 and 2000. The December data captured during CRPAQS were 40 to 60% greater than historic data in terms of averages but 40 to 50% lower in terms of peak values. The most significant difference between CRPAQS and historic concentrations was in the magnitude of peak concentrations. Even though the CRPAQS period included very severe winter episodes, peak CRPAQS PM<sub>10</sub> concentrations, unlike PM<sub>2.5</sub>, were generally lower than historic peaks. The highest PM<sub>10</sub> values were about 100 µg/m<sup>3</sup> lower than historic peaks. Possible reasons why CRPAQS had lower PM<sub>10</sub> but higher PM<sub>2.5</sub> peaks compared to historic levels include:

- 1) Better coverage - The assessment of historic levels is more accurate for PM<sub>10</sub> than for PM<sub>2.5</sub> because the PM<sub>10</sub> network had better spatial and temporal coverage.
- 2) Control measures - PM<sub>10</sub> concentrations were reduced over the years as a result of control measures, especially fugitive dust controls.
- 3) Seasonality - While the high PM<sub>2.5</sub> season occurs only in winter, the PM<sub>10</sub> season encompasses fall as well. The fall and winter concentrations are driven by different phenomena and are different chemically, with fall mass driven by fugitive dust and winter driven by ammonium nitrate and carbon. While winter concentrations were high during CRPAQS, the lack of fugitive dust driven episodes kept fall concentrations rather low. The weather during the CRPAQS winter periods may have been unusually conducive to PM<sub>2.5</sub> formation and accumulation.

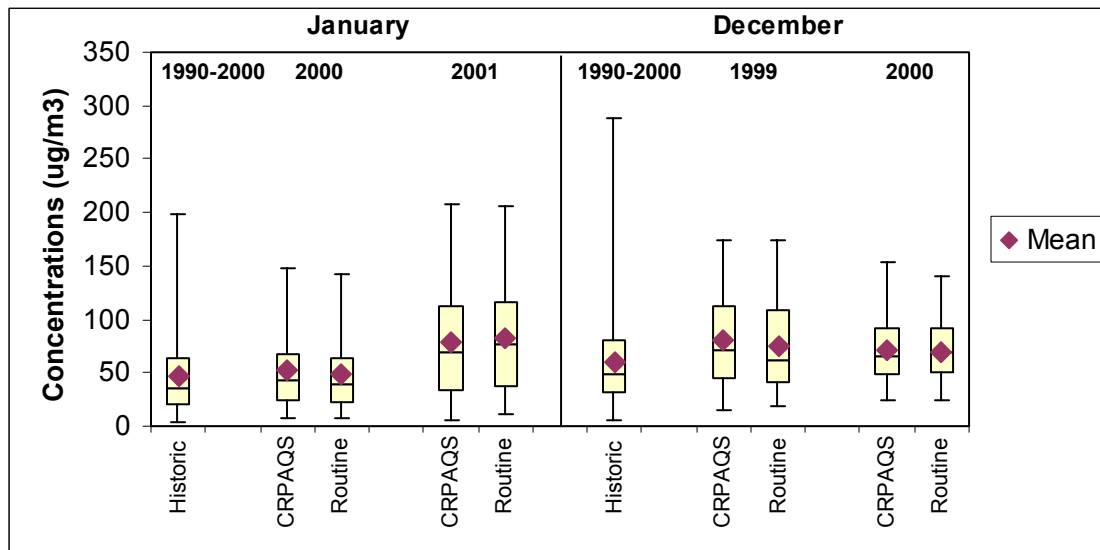
**Figure 5-10 PM<sub>10</sub> concentrations at urban monitoring sites in the San Joaquin Valley during CRPAQS between 12/1/99 and 2/18/01.**



**Figure 5-11 Comparison of fall PM<sub>10</sub> concentrations.**



**Figure 5-12 Comparison of winter PM<sub>10</sub> concentrations.**

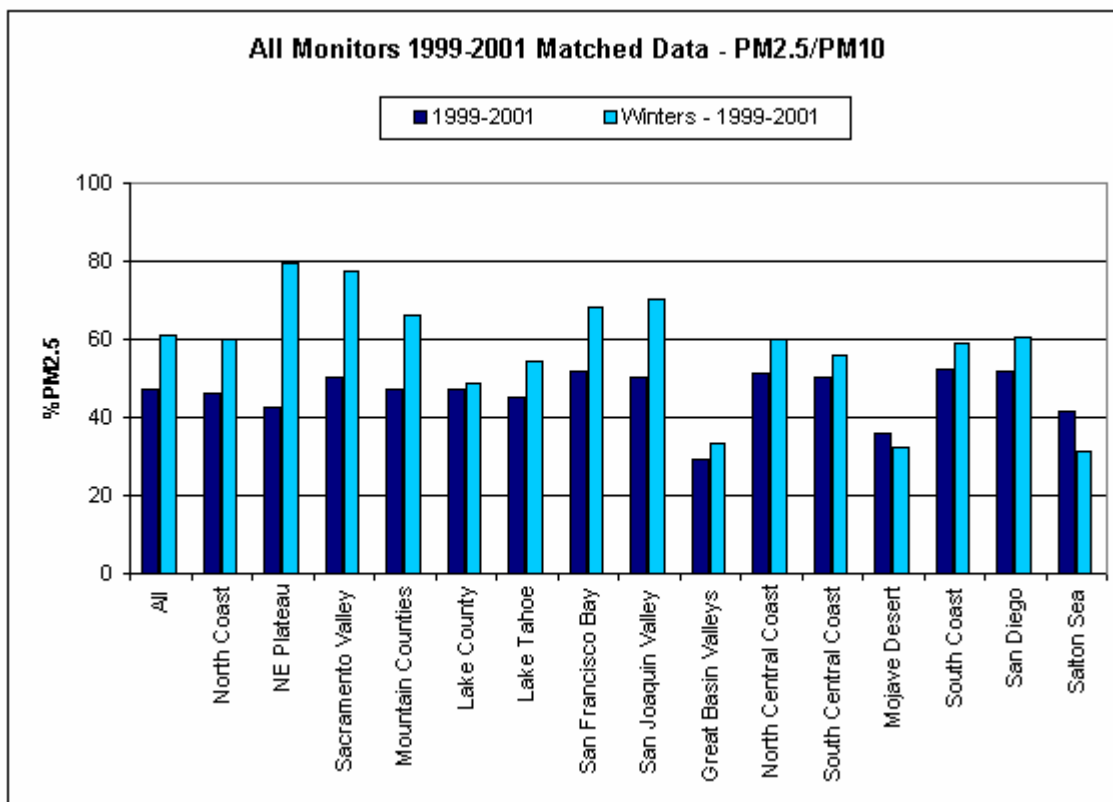


### 5.3 PM<sub>2.5</sub> to PM<sub>10</sub> Ratio

The ratio of PM<sub>2.5</sub> to PM<sub>10</sub> depends on factors that vary both spatially and temporally. In the San Joaquin Valley, these variations can be extreme. Peak PM<sub>10</sub> values are reached in the fall and early winter, with PM<sub>2.5</sub> reaching maximum levels primarily in the winter months (December, January, and February). Ambient data collected from the routine and CRPAQS networks were used to analyze these variations. Over 140 paired monitors (11 pair combinations) at 76 monitoring sites were evaluated.

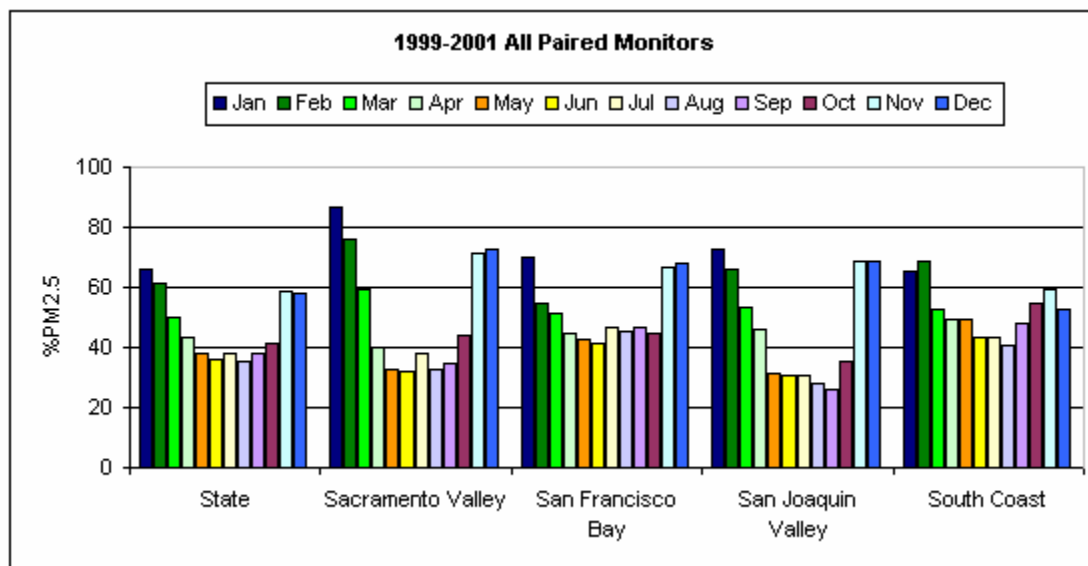
Averaged ratios from the paired monitors, mostly CRPAQS/SSI, were slightly higher in the southern portion of the State, lower in the desert and the northern air basins (Figure 5-13). This overall annual trend is reversed in the winter season, with the higher PM<sub>2.5</sub> fractions in the north and the lower in the south.

**Figure 5-13 1999-2001 - Annual and winter average PM<sub>2.5</sub>/ PM<sub>10</sub> ratios for all air basins.**



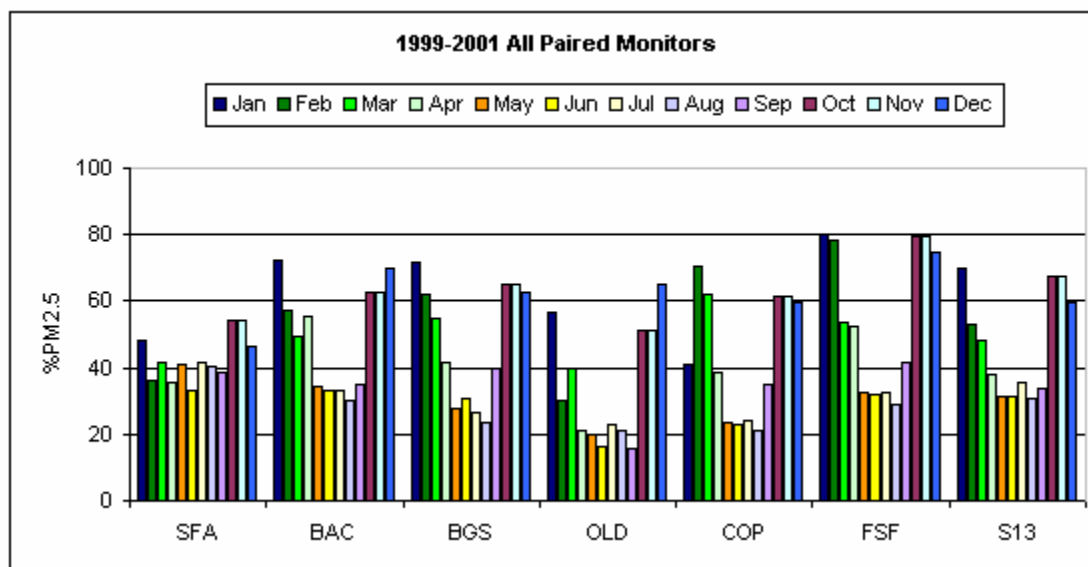
Annual trends (Figure 5-14), averaged on a monthly basis, show PM<sub>2.5</sub> contribution similar to the overall PM concentration trend but with a more abrupt increase from October to November. This increase is likely due to a shifting meteorological regime as well as changes in source contribution.

**Figure 5-14 Monthly variations in PM<sub>2.5</sub> as percent of PM<sub>10</sub> at selected air basins. (Based on the 1999-2001 data)**



Coastal air basins, such as the South Coast (Figure 5-14), and coastal sites such as San Francisco-Arkansas (SFA, Figure 5-15 below), exhibit far less variability in the percentage of PM<sub>2.5</sub> in total mass concentrations.

**Figure 5-15 Monthly variations in PM<sub>2.5</sub> as percent of PM<sub>10</sub> at selected monitoring sites. (Based on the 1999-2001 data)**



## 5.4 Chemical Components

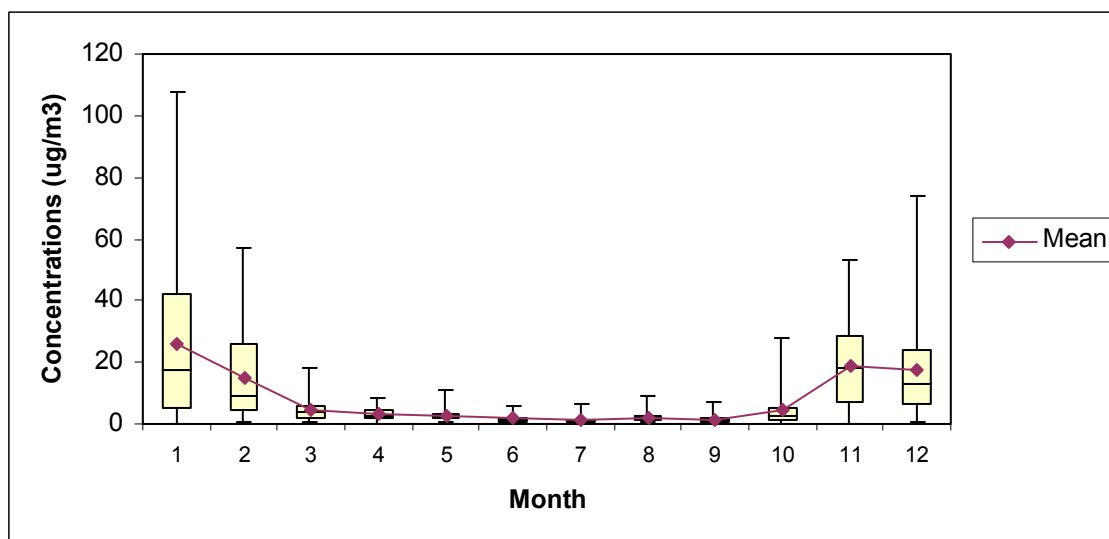
### 5.4.1 PM<sub>2.5</sub> Chemical Components

#### 5.4.1.1 San Joaquin Valley Air Basin

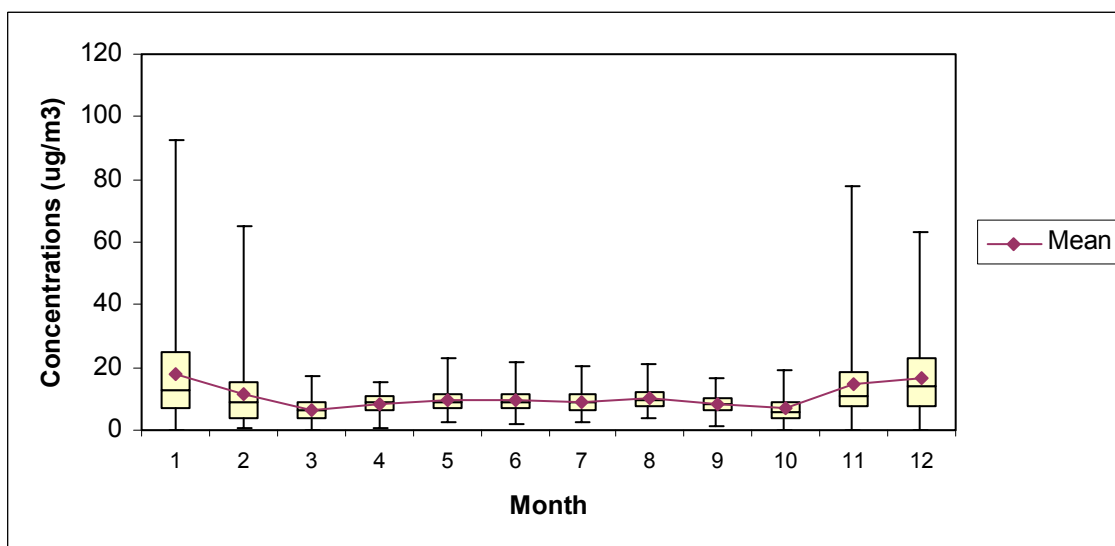
The two main components of PM<sub>2.5</sub> mass, ammonium nitrate and carbonaceous aerosols, exhibited a strong seasonal pattern. Ammonium nitrate concentrations were high during the winter months (January, February, November, and December) and low the rest of the year (Figure 5-16). The average ammonium nitrate concentration during the four winter months was  $20.2 \pm 18.7 \mu\text{g}/\text{m}^3$  while during the remaining eight months was only  $2.7 \pm 2.8 \mu\text{g}/\text{m}^3$  (Table 5-3). The winter peak concentrations reached  $107.9 \mu\text{g}/\text{m}^3$  while the highest value measured from March through October was  $20.2 \mu\text{g}/\text{m}^3$ . Carbonaceous aerosols concentrations exhibited similar, but less pronounced seasonal patterns (Figure 5-17). Concentrations were once again highest during the four winter months and lower the rest of the year, but the difference was less significant. The average winter concentration was  $16.0 \pm 13.4 \mu\text{g}/\text{m}^3$  while the average for March through October was  $8.5 \pm 3.8 \mu\text{g}/\text{m}^3$  (Table 5-3). The peak concentrations were  $92.3 \mu\text{g}/\text{m}^3$  for winter and  $22.9 \mu\text{g}/\text{m}^3$  for March through October. Figure 5-18 compares monthly average ammonium nitrate and carbonaceous aerosols concentrations. Concentrations of carbonaceous aerosols were about 20% lower than ammonium nitrate during winter but three times higher during the rest of the year, resulting in a much flatter seasonal pattern.

Urban and rural sites in the San Joaquin Valley exhibited similar seasonal patterns in ammonium nitrate concentrations (Figure 5-19). However, organic and elemental carbon concentrations differed between urban and rural sites (Figure 5-20). At rural sites, monthly average concentrations of elemental and organic carbon were almost flat across the year. Average concentrations for the summer months were slightly higher than winter, with August having the highest monthly average at about  $8 \mu\text{g}/\text{m}^3$ . At urban sites, organic and elemental carbon concentrations were highest during winter and lowest from March through October.

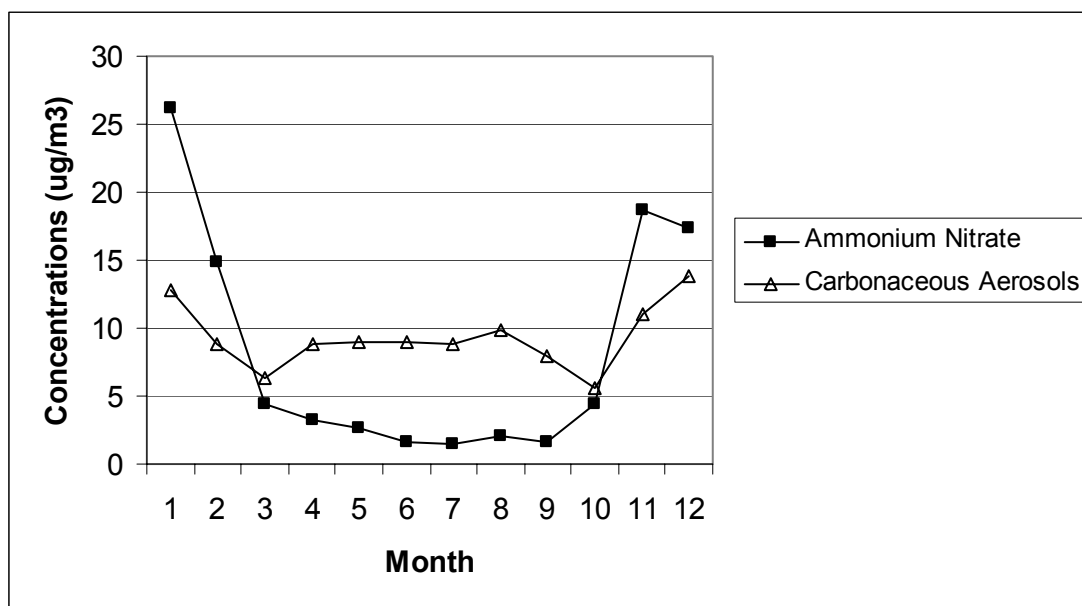
**Figure 5-16 Monthly variations in PM<sub>2.5</sub> ammonium nitrate concentrations in the San Joaquin Valley (12/1/99-2/8/01).**



**Figure 5-17 Monthly variations in carbonaceous aerosols concentrations in the San Joaquin Valley between 12/1/99 and 2/18/01.**



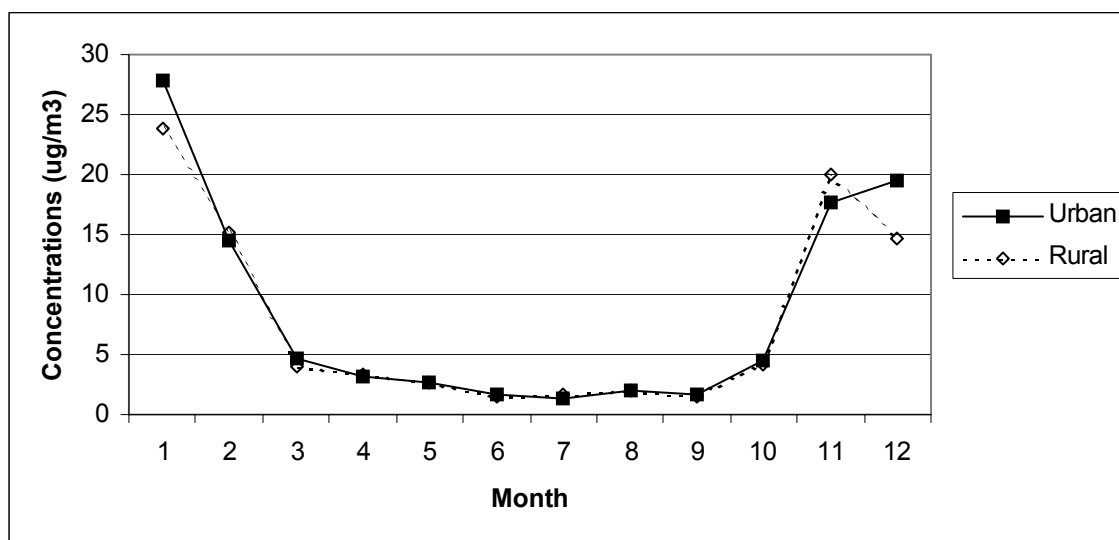
**Figure 5-18 Comparison of monthly average concentrations for ammonium nitrate and carbonaceous aerosols.**



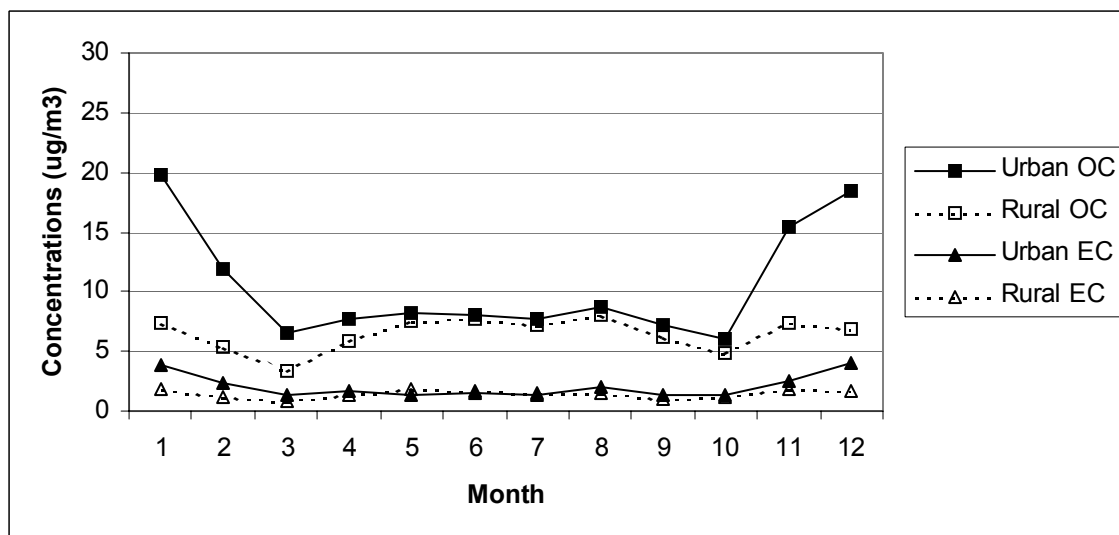
**Table 5-3 Comparison of seasonal pattern for ammonium nitrate and carbonaceous aerosols.**

Statistics	Season	Ammonium Nitrate ( $\mu\text{g}/\text{m}^3$ )	Carbonaceous aerosols ( $\mu\text{g}/\text{m}^3$ )
Peak Concentrations	Winter	107.9	92.3
	Low Season	28.0	22.9
Average Concentrations	Winter	$20.2 \pm 18.7$	$16.0 \pm 13.4$
	Low Season	$2.7 \pm 2.8$	$8.5 \pm 3.8$

**Figure 5-19 Comparison of monthly average ammonium nitrate concentrations at urban and rural sites in the San Joaquin Valley.**



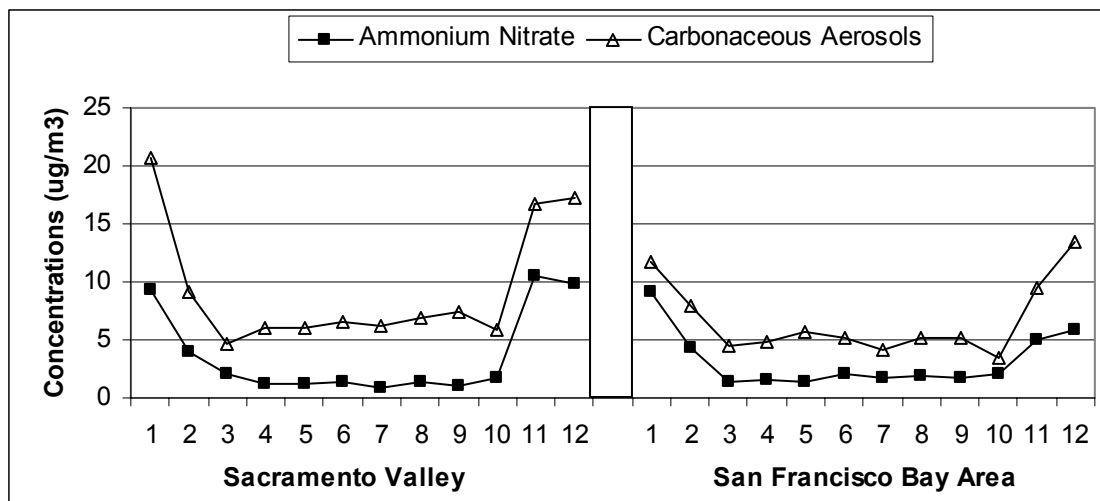
**Figure 5-20 Comparison of monthly average organic and elemental carbon concentrations at urban and rural sites in the San Joaquin Valley.**



#### 5.4.1.2 Sacramento Valley and the San Francisco Bay Area Air Basins

In the Sacramento Valley and the San Francisco Bay Area Air Basins, the two main components of  $PM_{2.5}$ , ammonium nitrate and carbonaceous aerosols, also exhibited a strong seasonal pattern. The highest concentrations were still measured during winter, similar to the San Joaquin Valley, but the relative proportions between ammonium nitrate and carbonaceous aerosols were different. In the San Joaquin Valley, monthly average concentrations of ammonium nitrate were higher than carbonaceous aerosols during the winter months but were lower the rest of the year. In the Sacramento Valley and the San Francisco Bay Area Air Basins, carbonaceous aerosols concentrations were consistently higher than ammonium nitrate across the year (Figure 5-21).

**Figure 5-21 Monthly average ammonium nitrate and carbonaceous aerosols concentrations in the Sacramento Valley and San Francisco Bay Area.**

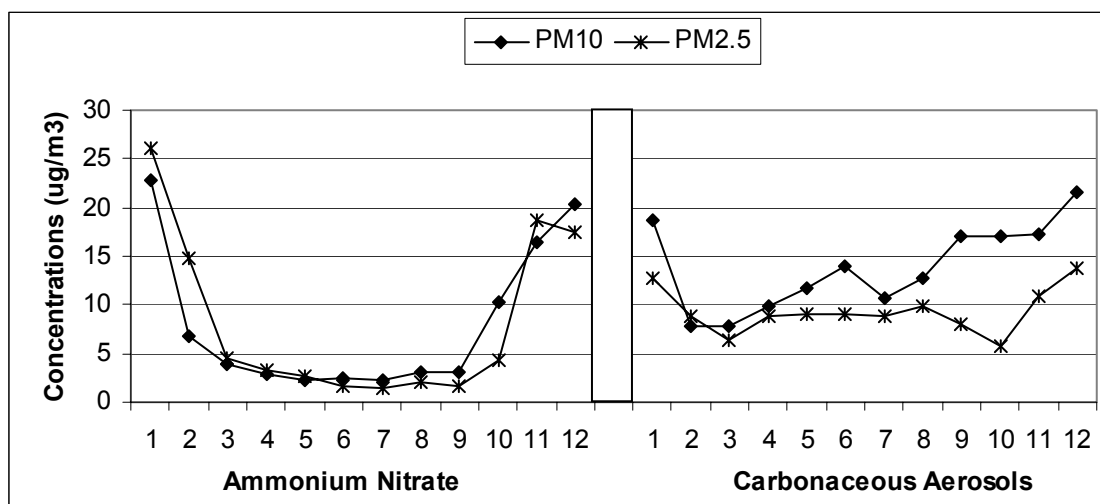


#### 5.4.2 $PM_{10}$ Chemical Components

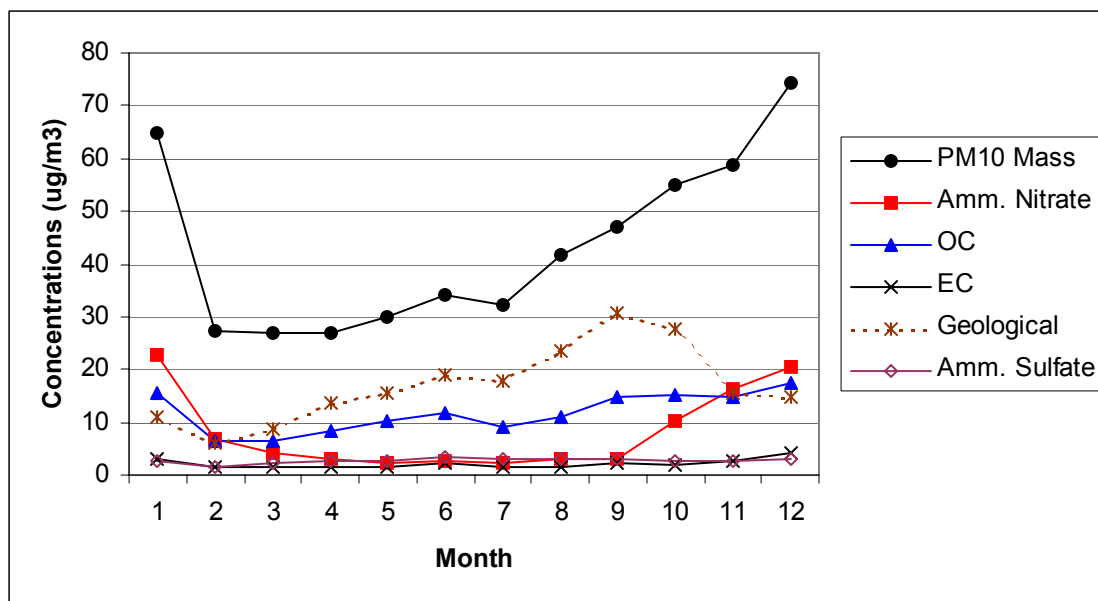
The main components of the  $PM_{10}$  mass were ammonium nitrate, carbonaceous aerosols, and geological material. The chemical composition data for  $PM_{10}$  and  $PM_{2.5}$  were collected at different monitoring sites and some of the small differences between components could be explained by differences in monitoring locations. Ammonium nitrate had a similar seasonal pattern for both size fractions,  $PM_{10}$  as well as  $PM_{2.5}$  (Figure 5-22), but with higher  $PM_{2.5}$  than  $PM_{10}$  concentrations for January, February, and November. Better filter handling procedures of  $PM_{2.5}$  samples, which reduce the loss of nitrate volatilization, might have contributed to higher  $PM_{2.5}$  ammonium nitrate than  $PM_{10}$ . Carbonaceous aerosols concentrations for the two size fractions did not track each other as well. While the  $PM_{10}$  fraction was always higher than for the  $PM_{2.5}$ , the difference was not uniform across the year. The difference was smallest from February through April, and highest in September and October. The average carbonaceous aerosols concentration in September and October was two to three times greater for the  $PM_{10}$  fraction. Concentrations of geological material were very small for the  $PM_{2.5}$  fraction but comprised a large fraction of  $PM_{10}$  mass, especially from April through October when they dominated the  $PM_{10}$  mass (Figure 5-23).

Concentrations of geological material had a unique seasonal pattern, different from ammonium nitrate and carbonaceous aerosols. They were highest during fall, from September through November (Figure 5-24). The Sacramento Valley and the San Francisco Bay Area Air Basins did not have enough PM<sub>10</sub> chemical composition data to analyze seasonal patterns.

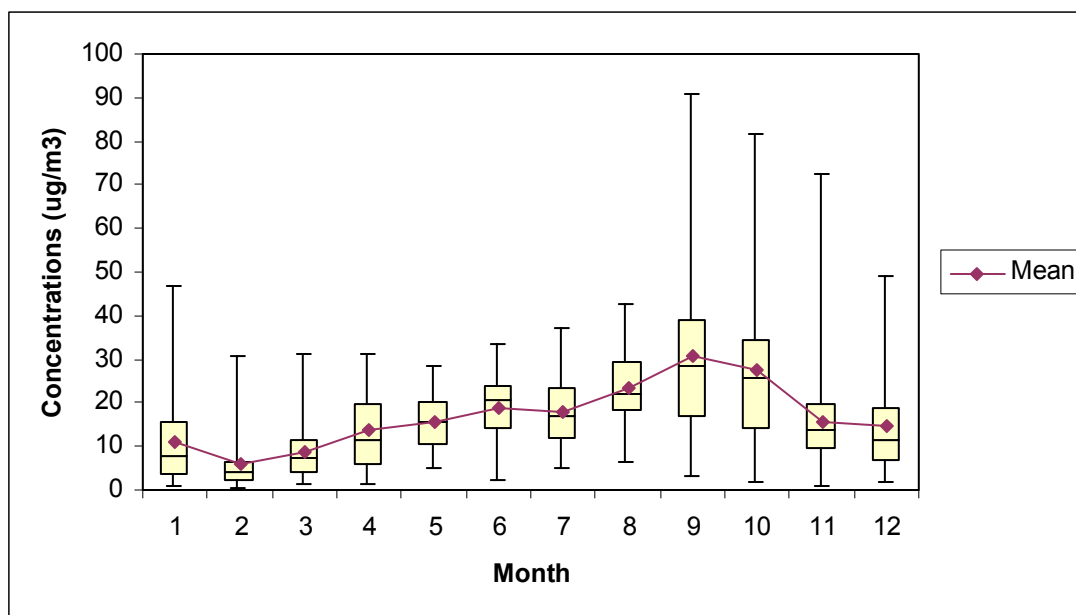
**Figure 5-22 Monthly average PM<sub>10</sub> and PM<sub>2.5</sub> ammonium nitrate and carbonaceous aerosols concentrations.**



**Figure 5-23 Monthly average concentrations of PM<sub>10</sub> mass and chemical components.**



**Figure 5-24 Monthly variations in PM<sub>10</sub> geological material concentrations in the San Joaquin Valley (12/1/99-2/8/01).**



## 6 SITE-TO-SITE VARIABILITY DURING THE STUDY PERIOD

The site-to-site variations were analyzed using matching data across all monitoring sites in a group. Monitoring sites missing several samples in a row were excluded from a comparison.

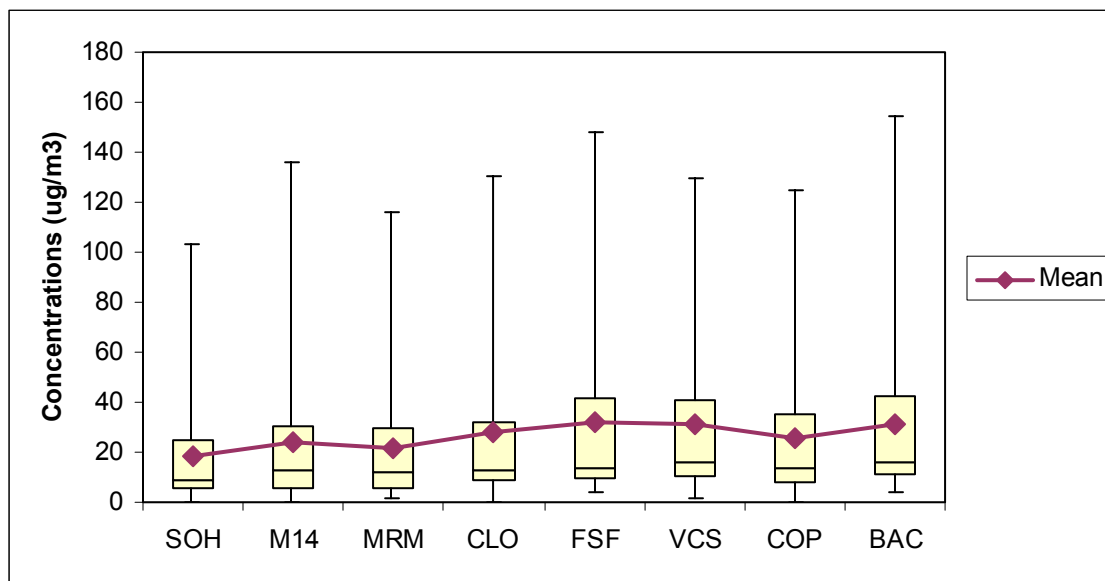
### 6.1 PM<sub>2.5</sub> Concentrations

The site-to-site variations in PM<sub>2.5</sub> concentrations were analyzed based on matching data collected at the key sites from December 1, 1999 through February 18, 2001. Matching data set improved site-to-site comparison, but excluded some peak values. The eight urban sites, shown in Figure 6-1, had 97 days with matching data while the rural sites, shown in Figure 6-2, had 79. PM<sub>2.5</sub> concentrations were lower in the northern San Joaquin Valley than in the central and southern Valley. Site-average PM<sub>2.5</sub> concentrations varied among the eight urban sites from 19 µg/m<sup>3</sup> at Stockton to 32 µg/m<sup>3</sup> at Fresno (Figure 6-1). The three highest sites, Fresno, Visalia, and Bakersfield, had similar mean (~31 µg/m<sup>3</sup>), median (~15 µg/m<sup>3</sup>), 25<sup>th</sup> and 75<sup>th</sup> percentiles (~11 µg/m<sup>3</sup> and 42 µg/m<sup>3</sup>, respectively) but different peak values. The highest peak, 155 µg/m<sup>3</sup>, was measured at Bakersfield. Fresno and Visalia measured peak concentrations of 148 µg/m<sup>3</sup> and 130 µg/m<sup>3</sup>, respectively. The number of days with PM<sub>2.5</sub> concentrations greater than the PM<sub>2.5</sub> NAAQS ranged from four at Stockton to 17 at Fresno. Bakersfield had 15 days with concentrations greater than PM<sub>2.5</sub> NAAQS while Visalia had 12. PM<sub>2.5</sub> concentrations at rural/intrabasin sites increased from the north to the south (Figure 6-2). Similar concentrations were found at Southwest Chowchilla and Helm. Pixley was the highest rural site. It had a mean concentration of 28 µg/m<sup>3</sup> and a peak of 165 µg/m<sup>3</sup>. The three rural/interbasin sites were significantly lower. The highest monitoring site in this group, Fellows, had an average concentration of about 18 µg/m<sup>3</sup> and a peak of 113 µg/m<sup>3</sup>.

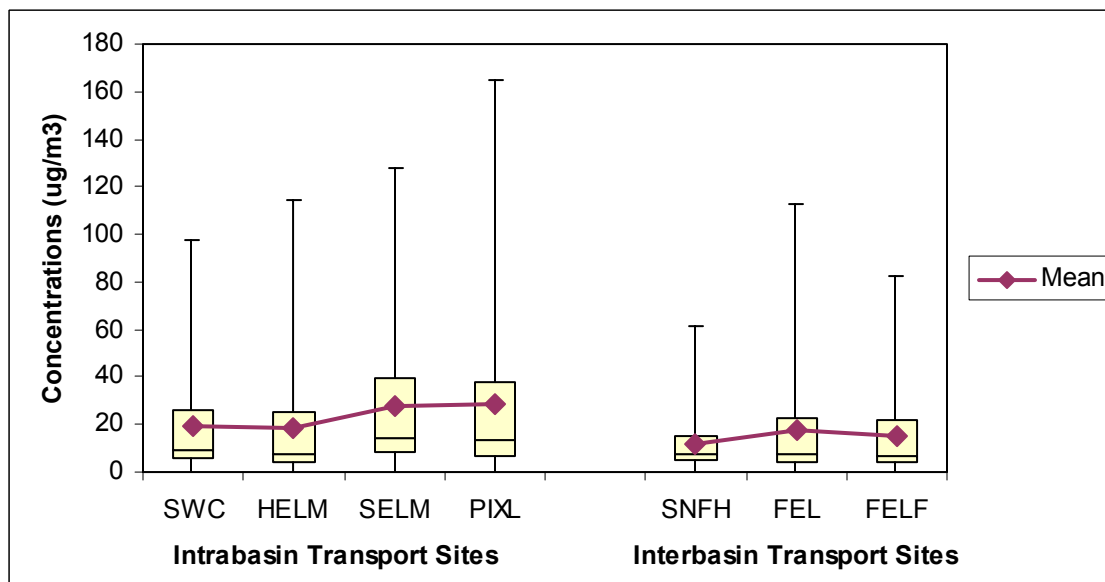
PM<sub>2.5</sub> concentrations were much lower in the San Francisco Bay Area and Sacramento Valley Air Basins. Figure 6-3 is based on 40 days with matching data for the San Francisco Bay Area Air Basin and Figure 6-4 is based on 47 days with matching data for the Sacramento Valley Air Basin. Based on the matching data, none of the monitoring sites in the San Francisco Bay Area exceeded the 24-hour PM<sub>2.5</sub> standard of 65 µg/m<sup>3</sup>. The highest site-average concentration of 17 µg/m<sup>3</sup> was found at San Jose-4<sup>th</sup>. The next two highest were found at San Jose-Tully (16 µg/m<sup>3</sup>) and Vallejo (15 µg/m<sup>3</sup>). Bodega Bay, with 10 µg/m<sup>3</sup>, had the lowest site-average concentration. The site-to-site variations were even more significant among the six Sacramento Valley sites. Based on 47 days with matching data, four sites exceeded the 24-hour standard. The peak concentration of 120 µg/m<sup>3</sup> was measured at Sacramento-Del Paso Manor. The site-average concentrations ranged from 11 µg/m<sup>3</sup> at Redding to 22 µg/m<sup>3</sup> at Sacramento-Del Paso Manor.

In addition to the graphs, which are based on matched data, Table 6-1 lists all PM<sub>2.5</sub> data collected at each monitoring site. Since Table 6-1 is based on all measured values, the reported peaks may be higher than those shown in the graphs, which are based on matched data.

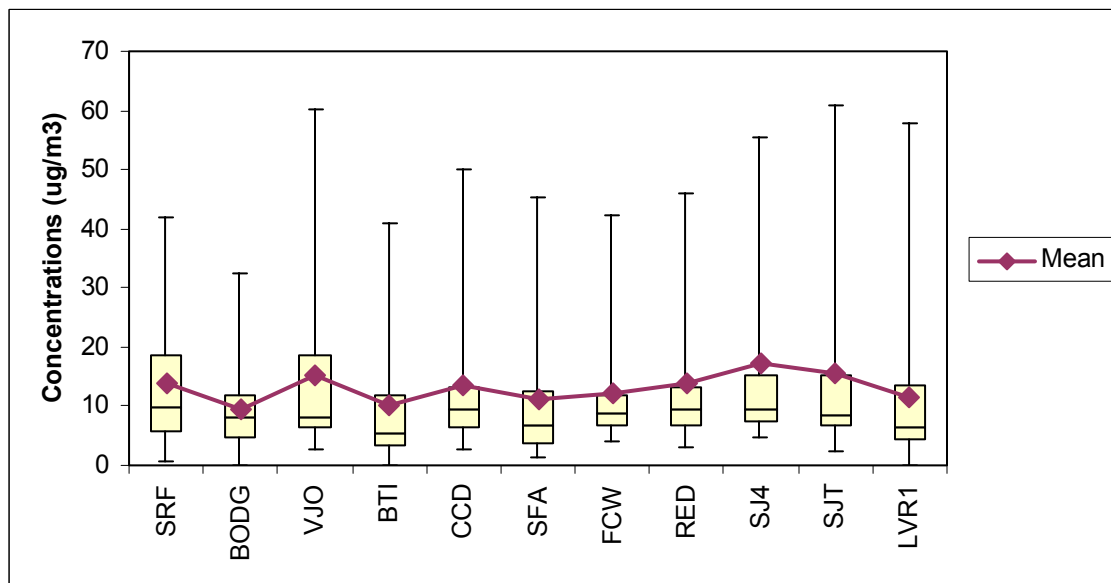
**Figure 6-1 Site-to-site variations in PM<sub>2.5</sub> concentrations at urban monitoring sites during CRPAQS between 12/1/99 and 2/18/01.**



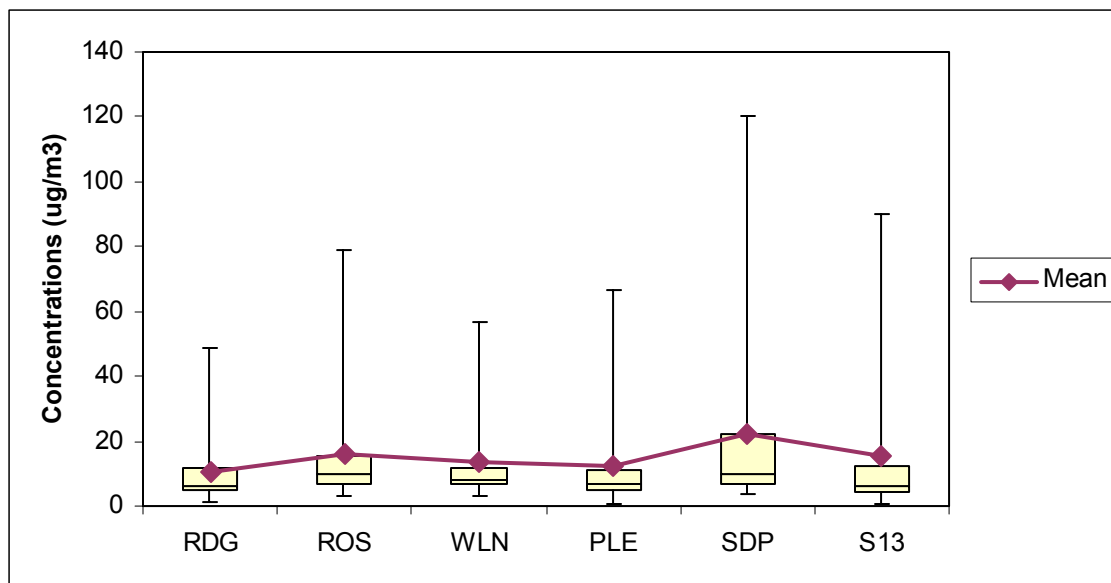
**Figure 6-2 Site-to-site variations in PM<sub>2.5</sub> concentrations at rural sites during CRPAQS from 12/1/99 through 2/18/01.**



**Figure 6-3 Site-to-Site variations in PM<sub>2.5</sub> concentrations in San Francisco Bay Area Air Basin during CRPAQS between 12/1/99 and 2/18/01.**



**Figure 6-4 Site-to-site variations in PM<sub>2.5</sub> concentrations in Sacramento Valley Air Basin during CRPAQS between 12/1/99 and 2/18/01.**



**Table 6-1 Summary of PM2.5 concentrations during CRPAQS (12/1/99-2/18/01)**

Basin	Site Name	Site ID	Obs Count	Concentrations (ug/m3)				Exceedance Days	
				Avg	STDEV	Peak	Date of Peak	Count	Avg Conc. (ug/m3)
NC	Eureka-Health Dept	EU6	71	10.9	6.7	29.0	1/31/01		
NC	Ukiah-County Library	UKC	70	8.7	6.8	38.3	1/7/01		
NCC	Santa Cruz-2544 Soquel Ave.	SCQ	87	8.7	4.4	23.3	11/20/00		
NCC	Salinas-Natividad Road #2	SL2	9	14.8	3.4	21.3	12/17/99		
NCC	Salinas-High School	SAL	81	8.0	5.0	26.0	11/20/00		
						26.0	1/7/01		
NEP	Alturas-W 4th Street	ALTR	72	10.2	9.3	40.0	12/26/99		
LC	Lakeport-Lakeport Blvd	LKL	41	4.0	2.6	15.1	1/7/01		
LT	South Lake Tahoe-Sandy Way	LTY	77	8.2	5.4	31.0	1/1/01		
LT	Echo Summit	ECHO	139	3.6	2.0	10.0	11/14/00		
MC	Quincy-N Church Street	QUI	124	11.8	9.6	45.0	1/1/01		
MC	Portola-161 Nevada Street	POL	79	13.2	13.4	58.0	1/7/01		
MC	Portola-Commercial Street	POL	6	25.2	11.4	39.0	1/7/00		
MC	Truckee-Fire Station	TRU	130	9.2	4.8	23.0	11/2/00		
MC	Grass Valley-Litton Building	GVL	57	5.9	4.7	27.0	3/31/00		
MC	San Andreas-Gold Strike Road	SGS	76	9.8	7.6	48.0	1/8/00		
MC	Angels Camp	ACP	85	4.5	3.6	18.9	1/7/00		
GBV	Mammoth Lakes-Gateway HC	MAG	30	17.5	10.4	34.0	1/4/01		
GBV	Keeler-Cerro Gordo Road	KCG	90	8.7	13.3	68.0	10/21/00	2	67.5
GBV	Olancha-Walker Creek Road	OLW	76	3.7	5.7	39.2	7/29/00		
GBV	Coso Junction-Highway 395	COSO	4	2.0	1.4	4.0	12/2/99		
SV	Redding-Health Dept Roof	RDG	69	10.5	9.2	49.0	1/7/01		
SV	Chico-Manzanita Avenue	CHM	74	18.1	20.0	98.0	11/20/00	3	80.3
SV	Colusa-Sunrise Blvd	CSS	138	9.7	8.1	47.0	12/23/99		
SV	Yuba City-Almond Street	YAS	75	13.4	12.4	56.0	12/26/99		
SV	Yuba City-Almond Street	YAS	75	13.4	12.4	56.0	1/7/01		
SV	Roseville-N Sunrise Blvd	ROS	73	14.9	13.9	79.0	12/20/99	1	79.0
SV	Woodland-Gibson Road	WLN	141	12.7	11.6	57.0	1/7/01		
SV	Pleasant Grove	PLE	70	11.1	12.7	66.3	12/20/99	1	66.3
SV	Sacramento-Del Paso Manor	SDP	129	17.0	20.0	120.0	1/1/01	7	85.3
SV	Sacramento-T Street	S13	393	14.6	15.1	90.2	12/20/99	6	72.7
SV	Sacramento-Health Dept Stockton Blvd	SST	162	17.6	17.8	86.0	12/20/99	5	71.8
SFB	Santa Rosa-5th Street	SRF	116	14.2	12.8	75.9	1/7/01	1	75.9
SFB	Bodega Marine Lab	BODG	80	11.6	9.4	37.7	2/2/01		
SFB	Vallejo-304 Tuolumne Street	VJO	117	18.0	17.6	90.5	12/26/99	3	86.2
SFB	Bethel Island	BTI	123	14.7	15.6	77.9	1/7/01	1	77.9
SFB	Concord-2975 Treat Blvd	CCD	251	14.8	11.8	68.2	1/6/01	1	68.2
SFB	San Francisco-Arkansas Street	SFA	277	14.7	13.2	76.6	1/21/01	3	72.6
SFB	Altamont Pass	ALT1	77	8.6	12.4	71.7	1/7/01	1	71.7
SFB	Fremont-Chapel Way	FCW	116	14.0	11.2	56.8	1/1/01		
SFB	Redwood City	RED	109	14.8	12.9	67.9	1/1/01	1	67.9
SFB	San Jose-4th Street	SJ4	293	18.6	16.0	70.0	12/27/99	1	70.0
SFB	San Jose-Tully Road	SJT	257	17.5	16.2	77.0	12/27/99	3	70.4
SFB	Livermore-793 Rincon Avenue	LVR1	128	15.6	16.4	95.4	1/7/01	1	95.4

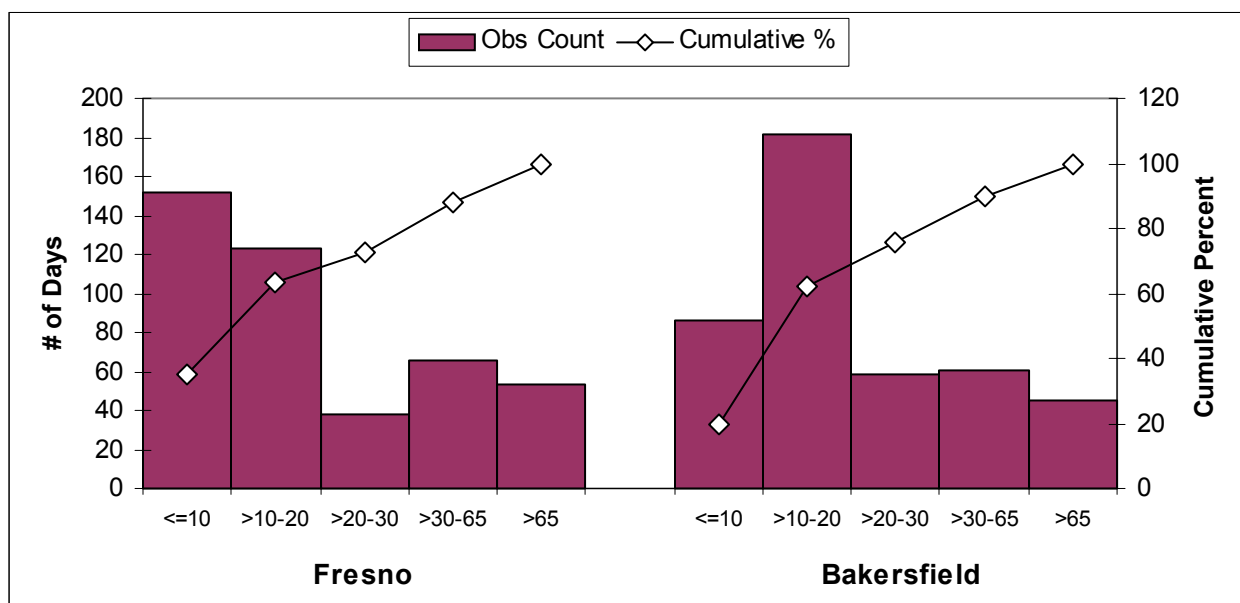
## Summary of PM2.5 concentrations (continued)

Basin	Site Name	Site ID	Obs Count	Concentrations (ug/m3)				Exceedance Days	
				Avg	STDEV	Peak	Date of Peak	Count	Avg Conc. (ug/m3)
SJV	Stockton-Hazelton Street	SOH	169	19.5	20.4	103.2	12/20/99	8	83.7
SJV	Modesto-14th Street	M14	172	24.1	25.3	136.1	1/7/01	16	86.8
SJV	Merced-2334 M Street	MRM	126	25.7	24.0	115.9	12/20/99	9	86.9
SJV	Pacheco Pass	PAC1	71	7.4	12.1	64.3	12/26/99		
SJV	Sierra Nevada Foothills	SNFH	125	14.5	13.4	70.2	1/1/00	1	70.2
SJV	SW Chowchilla	SWC	83	19.0	22.0	97.4	12/26/99	5	86.6
SJV	Clovis-N Villa Avenue	CLO	121	28.1	29.6	130.1	1/1/01	15	93.1
SJV	Residential area near FRS, with woodburning	FRES	79	36.1	41.3	169.4	1/1/01	17	106.9
SJV	Fresno-1st Street	FSF	436	27.3	30.8	148.3	1/1/01	54	98.2
SJV	Fresno MV	FREM	79	35.7	41.9	176.0	1/1/01	16	110.1
SJV	Feedlot or Dairy	FEDL	51	34.0	25.2	125.7	1/6/01	4	99.9
SJV	Agricultural fields/Helm-Central Fresno County	HELM	83	17.8	22.4	114.8	12/26/99	4	88.3
SJV	Selma(south Fresno area gradient site)	SELM	84	27.4	29.4	127.9	1/6/01	10	94.9
SJV	Visalia-N Church Street	VCS	157	30.9	29.7	130.0	1/5/01	20	95.3
SJV	Corcoran-Patterson Avenue	COP	113	28.0	29.7	145.0	1/6/01	12	97.6
SJV	Kettleman City	KCW	77	20.1	25.9	112.7	1/7/00	7	87.3
SJV	Fresno-Hamilton & Winery	FSE	89	23.1	18.6	88.2	1/7/01	2	85.9
SJV	ANGIOLA	ANGI	320	19.1	20.6	123.4	1/7/01	17	85.0
SJV	Pixley Wildlife Refuge	PIXL	82	27.9	33.5	164.9	1/6/01	11	99.8
SJV	Oildale-3311 Manor Street	OLD	65	23.5	29.9	140.6	1/1/01	8	90.7
SJV	Bakersfield-Golden State Hwy.	BGS	114	30.5	27.3	120.4	1/22/01	16	87.8
SJV	BAC Residential	BRES	58	41.0	43.1	158.9	1/1/01	14	105.7
SJV	Bakersfield-5558 California Ave.	BAC	441	26.3	25.6	154.7	1/5/01	44	89.3
SJV	Bakersfield-410 E Planz Road	BSE	116	23.6	22.4	114.2	1/22/01	10	85.5
SJV	Edison	EDI	75	30.3	37.6	179.2	1/5/01	11	106.5
SJV	Fellows	FEL	84	17.6	21.7	113.1	1/5/01	3	88.3
SJV	Foothills above Fellows	FELF	82	15.1	18.7	82.8	1/5/01	4	73.7
SJV	Tehachapi Pass	TEH2	75	6.5	6.0	35.4	12/8/00		
SJV	Taft College	TAC	13	20.1	17.7	52.0	12/23/99		
						52.0	1/7/00		
SCC	Atascadero-Lewis Avenue	ATL	72	12.2	11.5	57.6	1/1/01		
SCC	Carrizo Plain	CARP	63	6.2	7.4	32.6	1/19/01		
SCC	San Luis Obispo-Marsh Street	SLM	65	8.7	5.3	28.2	11/20/00		
SCC	Santa Maria-Broadway	SMY	71	9.4	4.3	28.7	2/24/00		
SCC	Santa Barbara-W Carillo Street	SBC	49	12.4	4.6	24.2	1/7/00		
						24.2	10/9/00		
SCC	Simi Valley-Cochran Street	SIM	127	13.6	9.0	55.0	11/29/00		
SCC	El Rio-Rio Mesa School #2	ELM	131	11.9	6.7	45.7	11/29/00		
SCC	Thousand Oaks-Moorpark Road	THM	137	13.2	8.5	53.7	11/29/00		
SCC	Piru-3301 Pacific Avenue	PIR	18	10.7	10.2	38.0	11/29/00		
MD	Edwards AFB	EDW	50	5.3	3.7	16.9	9/21/00		
MD	Ridgecrest-Las Flores Avenue	RGI	117	7.8	5.2	38.6	1/1/00		
MD	China Lake-Powerline Road	CHL	60	3.4	9.8	74.5	1/7/00	1	74.5
MD	Mojave-923 Poole Street	MOP	124	5.6	4.6	28.7	12/11/00		
MD	Lancaster-W Pondera Street	LWP	138	11.4	5.2	36.0	12/11/00		
MD	Victorville-14306 Park Avenue	VIA	133	12.2	5.4	31.0	12/11/00		
						31.0	1/7/01		
MD	Victorville-Armagosa Road	VIA	15	10.9	4.4	20.4	12/14/99		

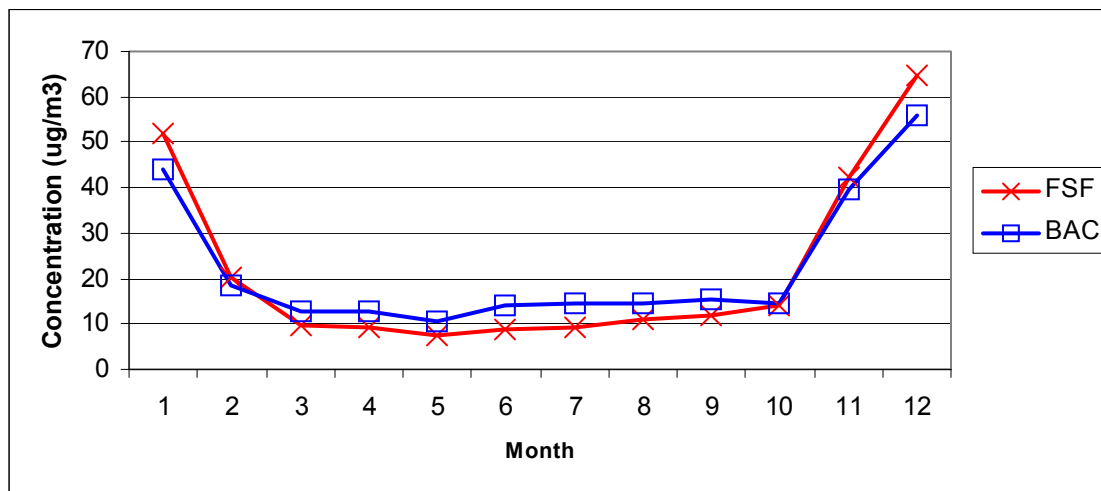
### 6.1.1 Comparison of PM<sub>2.5</sub> Concentrations at Fresno-1<sup>st</sup> Street and Bakersfield-California

Monitoring sites at Fresno-1<sup>st</sup> Street and Bakersfield-California, based on 432 days with matching data, achieved similar average concentrations of 27  $\mu\text{g}/\text{m}^3$  and 26  $\mu\text{g}/\text{m}^3$ , respectively. The peak concentrations were also similar, 148  $\mu\text{g}/\text{m}^3$  at Fresno and 155  $\mu\text{g}/\text{m}^3$  at Bakersfield. However, the distribution of concentrations was significantly different (Figure 6-5). The Fresno-1<sup>st</sup> Street site had more days with very low or very high concentrations while Bakersfield had more days in the 10  $\mu\text{g}/\text{m}^3$  to 20  $\mu\text{g}/\text{m}^3$  range. The number of days with concentrations less than 10  $\mu\text{g}/\text{m}^3$  was almost two fold higher at Fresno than Bakersfield (152 and 86 days, respectively). On the other hand, Bakersfield had about 60 more days (182 days at Bakersfield versus 123 at Fresno) with concentrations between 10  $\mu\text{g}/\text{m}^3$  and 20  $\mu\text{g}/\text{m}^3$ . Very high concentrations, exceeding the 24-hour PM<sub>2.5</sub> standard, were measured on 53 days at Fresno and 45 days at Bakersfield. The seasonal patterns were also different at the two sites. Monthly average concentrations were higher at Fresno during winter, slipping below Bakersfield during summer (Figure 6-6).

**Figure 6-5 Histogram of PM<sub>2.5</sub> concentrations at Bakersfield at Fresno during CRPAQS (12/1/99-2/18/01).**



**Figure 6-6 Comparison of monthly average PM<sub>2.5</sub> concentrations at Fresno and Bakersfield.**



## 6.2 PM<sub>10</sub> Concentrations

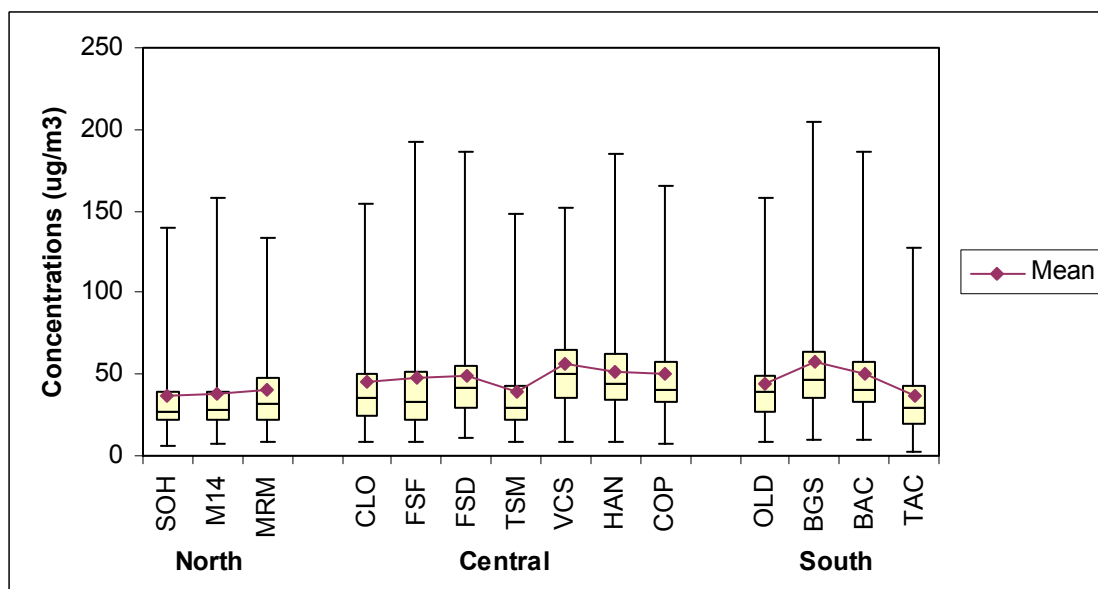
PM<sub>10</sub> concentrations, similar to PM<sub>2.5</sub>, were lower in the northern than in the central and southern San Joaquin Valley (Figure 6-7). In the northern Valley, site-average concentrations ranged from 36 µg/m<sup>3</sup> at Stockton to 41 µg/m<sup>3</sup> at Merced. In the central and southern Valley, Bakersfield-Golden with an average of 58 µg/m<sup>3</sup> and a peak of 205 µg/m<sup>3</sup> was the highest site. Visalia had the second highest site-average concentration (56 µg/m<sup>3</sup>), while Fresno-1<sup>st</sup> Street site had the second highest peak (193 µg/m<sup>3</sup>).

In the San Francisco Bay Area, site-to-site variations in concentrations were different for PM<sub>10</sub> than for PM<sub>2.5</sub>. Figure 6-8 illustrates site-to-site variations in PM<sub>10</sub> concentrations in the San Francisco Bay Area Air Basin. The San Jose-4<sup>th</sup> Street site was the highest site for both size fractions. However, the San Francisco-Arkansas site had high PM<sub>10</sub> but low PM<sub>2.5</sub> concentrations. A monitoring site at Vallejo, on the other hand, had high PM<sub>2.5</sub> but low PM<sub>10</sub> concentrations.

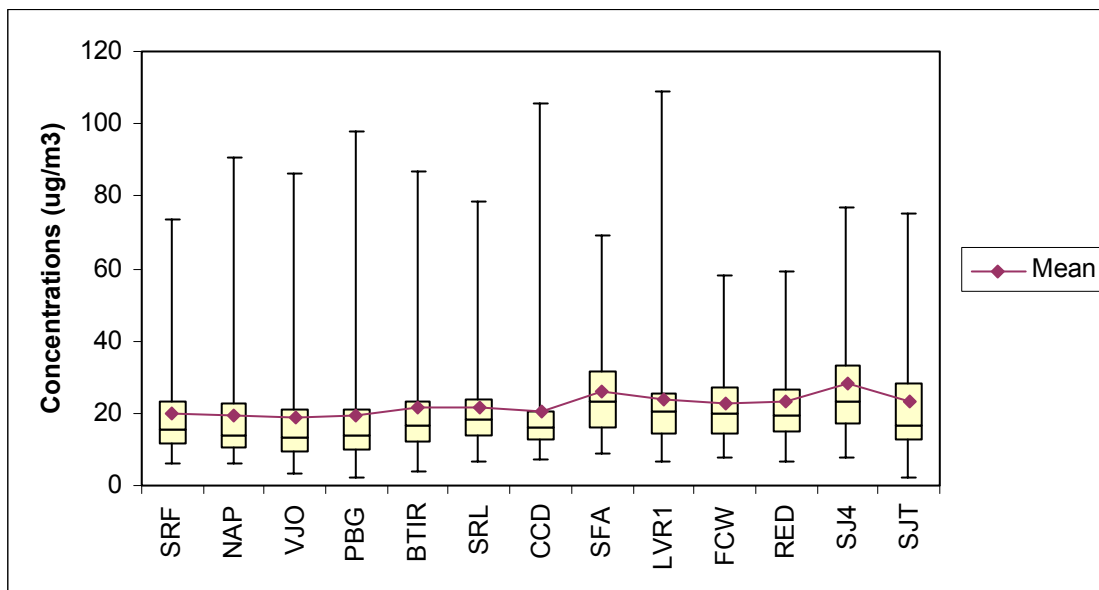
In the Sacramento Valley Air Basin, four monitoring sites (Chico-Manzanita, Yuba City, West Sacramento, and Sacramento-Branch Center) exhibited similar site-averaged concentrations of about 30 µg/m<sup>3</sup> (Figure 6-9). Sacramento-Del Paso Manor, the highest PM<sub>2.5</sub> site, was not one of the higher PM<sub>10</sub> sites.

In addition to graphs, which are based on matching data, Table 6-2 lists all PM<sub>10</sub> data collected at each monitoring site during CRPAQS. Similar to PM<sub>2.5</sub>, peak values may be higher in the unmatched data set.

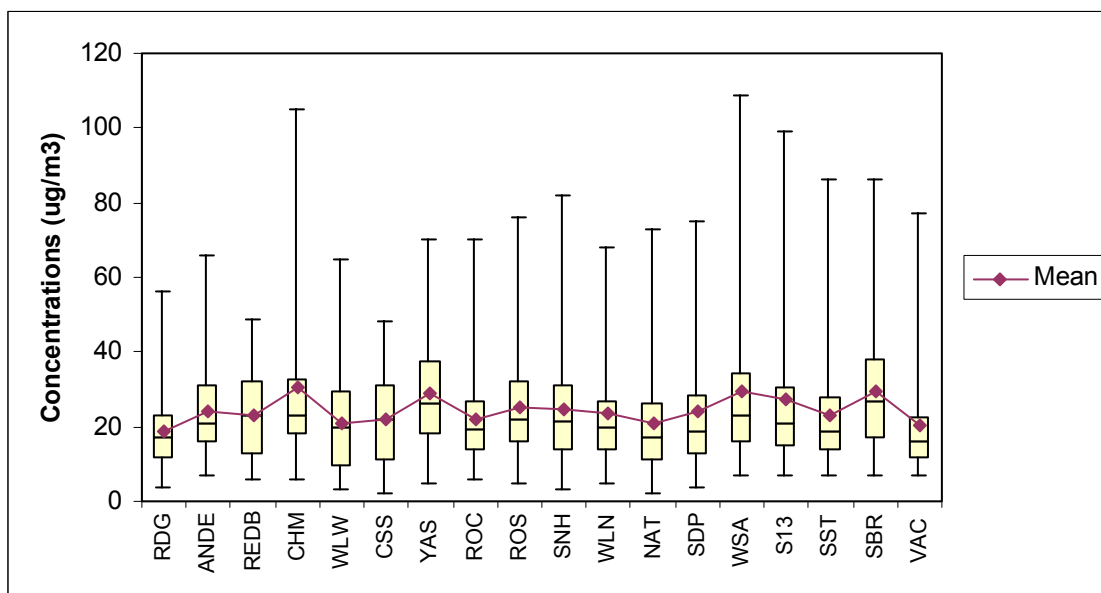
**Figure 6-7 PM<sub>10</sub> concentrations in the San Joaquin Valley during CRPAQS from 12/1/99 through 2/18/01.**



**Figure 6-8 PM<sub>10</sub> concentrations in the San Francisco Bay Area Air Basin during CRPAQS from 12/1/99 through 2/18/01.**



**Figure 6-9 PM<sub>10</sub> concentrations in the Sacramento Valley Air Basin during CRPAQS from 12/1/99 through 2/18/01.**



**Table 6-2 Summary of PM10 concentrations during CRPAQS (12/1/99-2/18/01)**

Basin	Site Name	Site ID	Obs Count	Concentrations (ug/m3)				Exceedance Days	
				Avg	STDEV	Peak	Date of Peak	Count	Avg Conc. (ug/m3)
NC	Crescent City, 880 Northcrest Drive	CREC	68	18.1	8.3	43.9	3/31/00		
NC	Eureka-Health Dept 6th and I Street	EU6	76	22.5	12.8	63.5	1/31/01		
NC	Weaverville-Courthouse	WEAV	73	22.4	13.1	59	1/15/01		
NC	Fort Bragg-N Franklin Street	BRAG	74	23.5	11.1	49	6/23/00		
NC	Willits-Firehouse	WILL	75	18.3	9.1	48	11/8/00		
NC	Ukiah-County Library	UKC	75	18.1	9.2	46	12/20/00		
NC	Cloverdale	CLV	72	13.8	10.5	58	1/7/01		
NC	Healdsburg-133 Matheson Street	HDB	71	15.3	8.7	57	1/7/01		
NC	Guerneville-Church and 1st	GUER	73	16.7	9.4	59	1/7/01		
NCC	Davenport	DVP	74	26.6	11.1	50	3/31/00		
						50	10/21/00		
NCC	Santa Cruz-2544 Soquel Avenue	SCQ	76	16.5	6.9	33	1/7/01		
NCC	Watsonville-Airport Boulevard	WAA	75	17.7	7.6	37	1/7/01		
NCC	Hollister-Fairview Road	HST	74	15.5	6.9	40	8/16/00		
NCC	Moss Landing - Sandholt Road	MLS	74	29.8	14.0	74	10/21/00		
NCC	Salinas-Natividad Road #2	SL2	11	19.1	8.3	29	1/7/00		
NCC	Carmel Valley-Ford Road	CMV	73	12.8	4.5	27	8/16/00		
NCC	King City-750 Metz Road	KCM	73	17.6	10.3	47	5/30/00		
NEP	Yreka-Foothill Drive	YRK	69	15.7	7.1	34	11/20/00		
NEP	Lava Beds Natl Monument	LAV	68	5.2	4.8	27.3	12/8/00		
NEP	Mt Shasta-N Old Stage Road	MSH	69	13.8	9.2	52.8	8/4/00		
NEP	Alturas-W 4th Street	ALTR	73	24.3	16.5	79.2	12/8/00		
NEP	Susanville-Russel	SVR	45	37.5	19.4	87	1/7/01		
LC	Lakeport-Lakeport Blvd	LKL	74	10.4	4.9	22	8/22/00		
LT	South Lake Tahoe-Sandy Way	LTY	74	20.6	11.0	51	1/1/01		
MC	Chester-222 1st Avenue	CHES	34	24.5	10.9	50	1/25/00		
MC	Quincy-N Church Street	QUI	72	23.5	14.7	73	8/22/00		
MC	Portola-161 Nevada Street	POL	16	34.6	14.5	75	5/30/00		
MC	Portola-Commercial Street	POL	6	40.3	21.9	77	1/7/00		
MC	Loyalton-W 3rd Street	LOYA	34	20.0	8.7	39	5/30/00		
						39	12/29/99		
MC	Truckee-Glenshire Fire Station	TRUG	33	23.7	11.9	57	6/5/00		
MC	Truckee-Fire Station	TRU	34	24.1	12.2	50	3/1/00		
MC	Grass Valley-Henderson Street	GVH	9	18.4	7.4	33	1/1/00		
MC	Placerville-Gold Nugget Way	PGN	71	15.7	7.7	38	1/1/00		
MC	San Andreas-Gold Strike Road	SGS	76	17.7	7.2	36	1/19/01		
MC	Yosemite Village-Visitor Center	YOY	71	26.2	15.7	98	12/26/00		
GBV	Mono Lake-Simis Residence	SIMU	114	11.8	16.9	133	12/2/99		
GBV	Lee Vining-SMS	LEEV	137	14.2	8.4	62	2/3/00		
GBV	Mammoth Lakes-Gateway HC	MAG	25	29.0	17.7	76	1/31/01		
GBV	Lone Pine-E Locust Street	LPE	17	14.9	10.4	44	12/2/99		
GBV	Keeler-Cerro Gordo Road	KCG	443	43.9	120.7	1308	2/6/01	19	500.7
GBV	Olancho-Walker Creek Road	OLW	73	19.7	24.1	176	3/31/00	1	176.0
GBV	Coso Junction-Highway 395 Rest Area	COSO	136	12.9	12.9	74	7/29/00		
GBV	Flat Rock-Highway 190	FLR	31	48.4	143.3	683	2/8/01	2	565.5
GBV	Shell Cut-Highway 190	SHL	27	20.1	49.5	208	2/6/01	2	189.5

## Summary of PM10 concentrations (continued)

Basin	Site Name	Site ID	Obs Count	Concentrations (ug/m3)				Exceedance Days	
				Avg	STDEV	Peak	Date of Peak	Count	Avg Conc. (ug/m3)
SV	Redding-Health Dept Roof	RDG	72	18.7	9.8	56	1/7/01		
SV	Anderson-North Street	ANDE	73	24.2	11.3	66	1/7/01		
SV	Red Bluff-Riverside Drive	REDB	71	23.4	11.5	49	8/22/00		
SV	Chico-Manzanita Avenue	CHM	85	31.0	20.4	105	1/1/01		
SV	Paradise-Fire Station #1	PFS	1	10.0		10	2/18/01		
SV	Willows-E Laurel Street	WLW	72	21.7	12.8	65	10/3/00		
SV	Colusa-Sunrise Blvd	CSS	74	23.2	12.1	55	10/6/00		
SV	Yuba City-Almond Street	YAS	78	29.4	14.8	70	8/22/00		
SV	Rocklin-Rocklin Road	ROC	87	22.3	11.0	70	12/20/99		
SV	Roseville-N Sunrise Blvd	ROS	85	25.8	13.2	76	12/20/99		
SV	North Highlands-Blackfoot Way	SNH	72	25.5	15.6	82	1/1/00		
						82	12/28/00		
SV	Woodland-Gibson Road	WLN	74	24.4	15.1	68	12/26/99		
						68	12/20/99		
SV	Sacramento-3801 Airport Road	NAT	60	21.0	14.3	73	11/20/00		
SV	Sacramento-Del Paso Manor	SDP	79	23.2	15.6	75	12/20/99		
SV	West Sacramento-15 <sup>th</sup> Street	WSA	72	29.4	20.8	109	12/20/99		
SV	Sacramento-T Street	S13	85	28.4	18.7	99	12/20/99		
SV	Sacramento-Health Dept Stockton Blvd	SST	53	23.7	14.9	86	2/18/00		
SV	Sacramento-Branch Center Road	SBR	69	28.7	15.9	86	12/20/99		
SV	Vacaville-Merchant Street	VAC	75	20.5	13.9	77	1/7/01		
SFB	Santa Rosa-5 <sup>th</sup> Street	SRF	74	19.8	12.4	73.7	1/7/01		
SFB	Napa-Jefferson Avenue	NAP	75	19.3	13.5	90.9	1/7/01		
SFB	Vallejo-304 Tuolumne Street	VJO	75	18.7	15.4	86.1	1/7/01		
SFB	Pittsburg-10 <sup>th</sup> Street	PBG	74	19.0	16.5	97.7	1/7/01		
SFB	Bethel Island Road	BTIR	75	21.7	15.5	86.8	1/7/01		
SFB	San Rafael	SRL	75	21.4	11.8	78.8	1/7/01		
SFB	Concord-2975 Treat Blvd	CCD	75	20.6	16.1	105.8	1/7/01		
SFB	San Francisco-Arkansas Street	SFA	74	25.9	13.8	69.4	12/26/99		
SFB	Livermore-Old 1 <sup>st</sup> Street	LVF	66	22.2	11.8	67.5	1/7/00		
SFB	Fremont-Chapel Way	FCW	75	22.7	12.2	58.1	11/20/00		
SFB	Redwood City	RED	75	23.2	12.8	59.2	1/1/01		
SFB	San Jose-4 <sup>th</sup> Street	SJ4	75	28.3	16.0	76.7	1/1/01		
SFB	San Jose-Tully Road	SJT	75	23.2	15.3	75.1	1/1/01		
SFB	Livermore-793 Rincon Avenue	LVR1	74	23.7	16.6	108.9	1/7/01		
SJV	Stockton-Wagner-Holt School	SWH	70	34.7	26.3	119	1/1/01		
SJV	Stockton-Hazelton Street	SOH	81	36.0	24.0	140	1/7/01		
SJV	Modesto-14 <sup>th</sup> Street	M14	153	36.5	27.7	158	1/7/01	1	158.0
SJV	Merced-2334 M Street	MRM	72	40.1	26.8	134	12/20/99		
SJV	Clovis-N Villa Avenue	CLO	69	45.3	31.8	155	1/1/01	1	155.0
SJV	Fresno-1 <sup>st</sup> Street	FSF	83	47.3	37.1	193	1/1/01	1	193.0
SJV	Fresno-Drummond Street	FSD	135	47.9	34.4	186	1/1/01	3	171.1
SJV	Turlock-S Minaret Street	TSM	74	38.8	26.6	148	1/7/01		
SJV	Visalia-N Church Street	VCS	135	51.0	31.4	152	12/20/99		
SJV	Hanford-S Irwin Street	HAN	150	47.7	32.1	185	1/7/01	2	170.3
SJV	Corcoran-Patterson Avenue	COP	173	48.2	33.5	174	12/17/99	2	169.5
SJV	Oildale-3311 Manor Street	OLD	134	43.7	31.7	195.2	1/4/01	2	176.6
SJV	Bakersfield-Golden State Highway	BGS	142	54.8	38.8	207.6	1/4/01	3	195.5
SJV	Bakersfield-5558 California Avenue	BAC	148	50.8	32.4	190	1/4/01	3	178.3
SJV	Taft College	TAC	86	39.0	25.6	128	1/1/01		

## Summary of PM10 concentrations (continued)

Basin	Site Name	Site ID	Obs Count	Concentrations (ug/m3)			Exceedance Days	
				Avg	STDEV	Peak	Date of Peak	Avg Conc. (ug/m3)
SCC	Paso Robles-Santa Fe Avenue	PRF	71	21.6	13.9	74	11/20/00	
SCC	Atascadero-Lewis Avenue	ATL	69	21.1	13.2	67	11/20/00	
SCC	Morro Bay	MBP	61	20.8	9.5	47	1/31/00	
SCC	San Luis Obispo-Marsh Street	SLM	73	18.9	8.1	44	8/16/00	
SCC	Arroyo Grande-Ralco Way	ARR	69	35.1	25.6	110.5	9/3/00	
SCC	Nipomo-Regional Park	TEF	72	20.5	14.4	113	7/29/00	
SCC	Nipomo-Guadalupe Road	NGR	71	28.7	23.1	106.7	6/11/00	
SCC	Lompoc-S H Street	LOM	74	21.3	9.8	49.3	10/27/00	
SCC	Vandenberg Air Force Base-STP Power	VBS	73	19.1	9.9	47.8	1/31/00	
SCC	Las Flores Canyon #1	CA1	72	16.4	9.0	49.2	5/19/00	
SCC	El Capitan Beach	ECP	75	19.7	9.0	45.8	8/10/00	
SCC	Santa Barbara-W Carillo Street	SBC	51	28.5	9.2	45	1/7/00	
						45	8/16/00	
SCC	Ojai-Ojai Avenue	OJO	74	25.3	9.2	50.3	1/7/01	
SCC	Piru-2 miles SW	PIR2	57	28.1	14.3	78.1	8/16/00	
SCC	Simi Valley-Cochran Street	SIM	72	26.3	13.2	69.1	10/21/00	
SCC	El Rio-Rio Mesa School #2	ELM	75	25.8	9.7	52.2	8/16/00	
SCC	Thousand Oaks-Moorpark Road	THM	72	28.2	16.9	99.5	8/16/00	
SCC	Santa Maria-906 S Broadway	O	75	24.8	10.3	53	8/16/00	
SCC	Piru-3301 Pacific Avenue	PIR	15	14.7	9.5	39.3	1/7/01	
SCC	Santa Maria-906 S Broadway	O	75	24.8	10.3	53	10/21/00	
MD	Trona-Athol and Telegraph	O	63	17.4	10.0	58	5/30/00	
MD	China Lake-Powerline Road	CHL	67	13.9	9.2	53	3/19/00	
MD	Mojave-923 Poole Street	MOP	72	18.5	10.2	44	10/21/00	
MD	Ridgecrest-100 West California Avenue	RGI	70	21.1	14.0	90	1/1/00	
MD	Barstow	BSW	69	26.9	12.6	69	3/19/00	
MD	Lancaster-W Pondera Street	LWP	5	41.8	24.8	85	12/2/99	
MD	Victorville-Armagosa Road	VIA	27	29.3	16.4	78	12/2/99	
MD	Hesperia-Olive Street	HES	73	34.7	17.4	109	12/8/99	
MD	Lucerne Valley-Middle School	LUC	72	21.1	13.6	58	9/28/00	
MD	Twentynine Palms-Adobe Road #2	TNP	74	20.2	11.1	62	8/22/00	
MD	San Jacinto - Young Street	SJY	4	11.0	3.7	15	1/25/01	
MD	San Jacinto-San Jacinto Street	SJSJ	4	14.8	5.9	23	2/6/01	

## 6.3 Chemical Components

This section examines the site-to-site variations in major chemical components of the PM<sub>2.5</sub> and PM<sub>10</sub> mass based on the data collected between December 1, 1999 and February 18, 2001. To the extent possible, the analysis is based on matching data. Only monitoring sites with fairly complete data for the entire duration of the study are included. The statistical parameters, including mean, standard deviation, minimum, maximum, 25<sup>th</sup>, 50<sup>th</sup>, and 75<sup>th</sup> percentiles, coefficient of variation, and count of observations are calculated for each site. Monitoring sites are compared within each air basin. In addition, monitoring sites in the San Joaquin Valley are grouped based on site characteristics into urban, rural/intrabasin, and rural/interbasin, and compared within a group. The main components of the PM<sub>2.5</sub> mass are ammonium nitrate and carbonaceous aerosols, which together

comprise over 80% of the PM<sub>2.5</sub> mass. Ammonium sulfate, although significantly lower in concentration, is also included in the comparison. Analysis of PM<sub>10</sub> chemical components includes geological material, carbonaceous aerosols, and ammonium nitrate.

### 6.3.1 PM<sub>2.5</sub> Chemical Components

Chemical composition data collected from December 12, 1999 through February 18, 2001 were compared for each monitoring site. Over 80% of PM<sub>2.5</sub> mass could be attributed to carbon and ammonium nitrate. Throughout the duration of the Study, these two major components had a wide range of concentrations, ammonium nitrate from less than 1 µg/m<sup>3</sup> to 108 µg/m<sup>3</sup> and carbon from less than 1 µg/m<sup>3</sup> to 92 µg/m<sup>3</sup>. Ammonium nitrate concentrations varied significantly temporally but were fairly uniform spatially. Concentrations of carbonaceous aerosols were much more uniform temporally but exhibited significant spatial variations. Over the course of CRPAQS, the average urban site experienced about 127% variation in ammonium nitrate concentrations but only 66% in carbonaceous aerosols concentrations.

Only the days with matching data for all sites in the same category were included in the analysis. For example, urban sites had 50 days with matching chemical composition data for the eight sites listed in Table 6-4. While this warranted a better site-to-site comparison, it resulted in a smaller database which excluded some of the peak values. Therefore, to take advantage of a larger data set, a separate comparison of just Fresno and Bakersfield was conducted. This comparison was based on 70 days with matching data (Table 6-5). Rural/intrabasin sites had 66 matching days (Table 6-6) and rural/interbasin had 69 (Table 6-7). Finally, to compare the three categories of sites (urban, rural/intrabasin, and rural/interbasin), a separate data set with matching data across all three categories was created. This set was based on only 35 days with matching data (Table 6-8).

On average, carbonaceous aerosols were the major component at urban sites. Figure 6-10 shows a box-and-whiskers plot of PM<sub>2.5</sub> carbonaceous aerosols concentrations at each urban site. The average carbonaceous aerosols concentration for the eight urban sites was 12.5 µg/m<sup>3</sup>. Fresno not only had the highest average concentration (17.9 µg/m<sup>3</sup>) but also the highest peak (60 µg/m<sup>3</sup> measured on February 3, 2001). The other urban sites were significantly lower, with average concentrations ranging from 9.6 µg/m<sup>3</sup> at Corcoran to 13.2 µg/m<sup>3</sup> at Bakersfield and peak concentrations ranging from 27 µg/m<sup>3</sup> at Stockton to 41 µg/m<sup>3</sup> at Bakersfield. Ammonium nitrate, with an average concentration of 9.3 µg/m<sup>3</sup>, was the second highest component at urban sites. Site-averaged ammonium nitrate concentrations had a very distinct pattern with concentrations increasing from north to south (Figure 6-11). The average concentration was lowest at Stockton (5 µg/m<sup>3</sup>) and highest at Visalia (12.4 µg/m<sup>3</sup>). The peak concentrations had an even more distinct spatial pattern, with a gradual increase to the south. The site furthest to the north, Stockton, had a peak concentration of 25 µg/m<sup>3</sup>. Fresno, located in the central part of the Valley, had a peak of 51 µg/m<sup>3</sup>, while Bakersfield, furthest to the south, had 77 µg/m<sup>3</sup>. Compared to carbonaceous aerosols, ammonium nitrate concentrations were more uniform spatially but less uniform temporally due to differences in formation and transport rates. Ammonium

sulfate concentrations were significantly lower than ammonium nitrate and did not have the same latitudinal gradient (Figure 6-12).

The relative proportions of carbonaceous aerosols to ammonium nitrate were strikingly different between the two major urban sites in the San Joaquin Valley, Bakersfield and Fresno (Table 6-5 and Figure 6-13). The average carbonaceous aerosols concentration, based on 70 days of matching data, exceeded ammonium nitrate concentration by 10% at Bakersfield and 100% at Fresno. When it comes to peak concentrations, however, carbonaceous aerosols were 45% higher than ammonium nitrate at Fresno but 50% lower at Bakersfield.

Ammonium nitrate, and not carbonaceous aerosols, dominated average  $PM_{2.5}$  concentrations at rural/intrabasin sites. Ammonium nitrate at these sites exhibited the same north to south progression in concentrations as urban sites (Figure 6-14). Southwest Chowchilla, with an average of  $8.5 \mu\text{g}/\text{m}^3$  and a peak of  $37 \mu\text{g}/\text{m}^3$ , had the lowest concentrations while Pixley, with an average of  $14.8 \mu\text{g}/\text{m}^3$  and a peak of  $100 \mu\text{g}/\text{m}^3$  had the highest. Carbonaceous aerosols, on average, were the second highest component in this group. Its concentrations exhibited a spatial dichotomy similar to urban, with sites around Fresno having much higher concentrations than the other rural sites (Figure 6-14). For example, Selma near Fresno had the peak carbonaceous aerosols concentration of  $28 \mu\text{g}/\text{m}^3$  while the second highest peak was almost  $10 \mu\text{g}/\text{m}^3$  lower. Ammonium sulfate concentrations once again were significantly lower than the other two components. Rural/interbasin sites had patterns similar to the rural sites located on the Valley floor (Figure 6-15).

In order to compare the three groups of sites, urban, rural/intrabasin, and rural/interbasin, a separate data set consisting of matching data for all sites was analyzed (Table 6-8). This data set included 35 days with matching data. The  $PM_{2.5}$  mass was dominated by carbon at an average urban site and by ammonium nitrate at an average rural site (Figure 6-16). Concentrations of ammonium nitrate depended more on location than on site characteristics. Monitoring sites on the Valley floor, both urban and rural, had the same ammonium nitrate average concentration of  $11 \mu\text{g}/\text{m}^3$ . Monitoring sites located on the outskirts of the Valley (rural/interbasin) were lower, about  $8 \mu\text{g}/\text{m}^3$ . Urban sites had the highest peak ammonium nitrate concentration of  $77 \mu\text{g}/\text{m}^3$ , followed by rural/intrabasin with  $69 \mu\text{g}/\text{m}^3$ , and rural/interbasin with  $57 \mu\text{g}/\text{m}^3$ . Carbonaceous aerosols concentrations depended more on site characteristics (urban vs. rural) than location. Concentrations were significantly lower in the rural than urban environment. The average difference was 40% to 50%, but increased to over 60% on peak days. Carbonaceous aerosols concentrations were also less variable than ammonium nitrate at each group of sites (Table 6-8). Monitoring sites located on the Valley floor (urban and rural/intrabasin) had about 50% less variation in carbonaceous aerosols concentrations than ammonium nitrate. For example, the average urban site had coefficient of variation of 69% for carbon and 122% for ammonium nitrate. The difference between the two components reached 60% at rural/interbasin sites, with coefficient of variation 58% for carbon and 144% for ammonium nitrate.

The fairly uniform ammonium nitrate concentrations across the Valley floor can be contrasted with carbonaceous aerosols concentrations that are primarily high in urban areas. These differences can be traced back to their origin and formation. Ammonium nitrate is considered a secondary pollutant (formed from directly emitted gasses by transformation in the atmosphere). Most of the carbonaceous aerosols, on the other hand, are considered a primary pollutant (directly emitted into the atmosphere as a particle). The fairly uniform ammonium nitrate concentrations throughout the San Joaquin Valley reflect a more regional secondary formation and mixing mechanism. In contrast, carbonaceous aerosols concentrations were higher in the urban environment due to the greater number of primary emission sources.

In addition to the summaries and graphs, based on matching data, Table 6-3 summarizes all PM<sub>2.5</sub> mass and chemical composition acquired during the study period.

**Table 6-3 Summary of PM2.5 chemical composition during CRPAQS (12/1/99-2/18/01)**

Basin	Site	Obs. Count	Average Concentration (ug/m3)							Peak Concentration (ug/m3)						
			PM2.5 Mass	Sum of Species	Amm. Nitrate	Amm. Sulfate	OC	EC	Geological	PM2.5 Mass	Sum of Species	Amm. Nitrate	Amm. Sulfate	OC	EC	Geological
GBV	OLW	57	4.1 ± 5.8	6.1 ± 5.4	0.4 ± 0.7	0.8 ± 0.5	3.1 ± 4.0	0.6 ± 0.9	0.9 ± 1.6	39.2	35.1	5.7	2.6	26.3	6.1	9.7
MC	ACP	75	5.0 ± 3.5	8.0 ± 3.8	1.4 ± 1.8	1.1 ± 0.6	4.0 ± 2.3	0.9 ± 0.6	0.4 ± 0.5	18.9	18.1	8.6	2.7	9.1	2.4	3.2
MD	CHL	45	2.8 ± 3.3	7.4 ± 5.1	0.7 ± 2.2	1.1 ± 0.6	4.1 ± 3.6	0.8 ± 0.6	0.5 ± 0.5	21.2	23.1	14.9	2.8	13.2	1.9	2.2
MD	MOP	59	5.0 ± 3.2	9.5 ± 5.0	1.0 ± 1.2	1.4 ± 0.9	5.1 ± 3.8	1.1 ± 0.6	0.6 ± 0.6	15.6	19.0	7.3	4.6	13.4	2.7	2.7
SFB	BODG	68	12.0 ± 9.3	11.5 ± 8.0	2.1 ± 4.1	1.9 ± 1.0	2.2 ± 2.3	0.4 ± 0.4	0.2 ± 0.1	37.7	36.9	21.7	4.9	8.7	2.1	0.5
SFB	BTI	80	15.4 ± 17.5	16.5 ± 13.9	6.3 ± 8.5	1.6 ± 0.9	5.9 ± 4.6	1.8 ± 1.4	0.4 ± 0.6	77.9	71.2	40.5	4.1	20.5	6.8	3.1
SFB	SFA	68	10.4 ± 10.9	13.3 ± 9.9	3.2 ± 5.5	1.9 ± 1.0	4.6 ± 3.8	1.9 ± 1.3	0.4 ± 0.5	63.4	55.5	32.8	5.7	18.8	5.0	2.7
SFB	PLE	64	10.8 ± 12.1	13.5 ± 10.1	3.7 ± 6.1	1.5 ± 1.0	5.6 ± 4.0	1.7 ± 1.0	0.4 ± 1.3	66.3	57.1	38.8	6.5	18.1	5.8	9.7
SFB	SJ4	105	15.9 ± 12.5	17.4 ± 13.0	4.0 ± 4.3	1.9 ± 1.1	8.8 ± 7.9	1.2 ± 1.1	0.6 ± 0.6	62.0	62.1	19.5	7.7	39.2	5.7	3.7
SFB	LVR1	79	14.2 ± 16.5	17.2 ± 14.4	4.2 ± 6.6	1.4 ± 0.9	7.9 ± 5.9	2.8 ± 2.4	0.3 ± 0.4	95.4	83.8	38.6	3.8	28.9	12.5	1.6
SJV	SOH	76	20.2 ± 23.3	22.5 ± 19.0	8.1 ± 12.8	1.9 ± 1.0	8.6 ± 5.1	2.6 ± 1.6	0.6 ± 1.1	103.2	98.2	67.5	4.7	23.2	7.4	9.1
SJV	M14	80	25.0 ± 28.5	26.6 ± 22.4	9.3 ± 13.1	2.0 ± 1.1	11.2 ± 7.7	2.9 ± 2.4	0.5 ± 0.6	136.1	101.4	63.1	5.1	33.9	10.7	3.4
SJV	MRM	80	23.5 ± 25.8	26.9 ± 22.1	10.1 ± 13.1	1.8 ± 0.9	11.3 ± 7.7	2.7 ± 1.7	0.6 ± 0.5	115.9	98.5	61.0	4.3	29.6	7.2	1.8
SJV	SNFH	87	13.6 ± 13.0	16.0 ± 10.7	5.2 ± 7.6	1.4 ± 0.8	7.1 ± 3.3	1.4 ± 0.7	0.5 ± 0.7	70.2	58.5	39.8	3.8	17.5	3.7	4.9
SJV	SWC	76	16.7 ± 19.1	17.9 ± 14.8	8.9 ± 11.3	1.6 ± 0.7	5.0 ± 3.3	1.5 ± 0.8	0.6 ± 1.1	97.4	89.1	63.4	3.6	17.5	4.2	8.1
SJV	CLO	70	30.6 ± 34.7	31.7 ± 27.9	13.2 ± 17.8	2.1 ± 1.1	12.1 ± 7.8	3.0 ± 2.2	0.9 ± 1.0	130.1	118.1	73.9	6.5	32.7	10.6	5.4
SJV	FRES	76	34.9 ± 38.9	35.5 ± 30.5	12.1 ± 14.6	2.2 ± 1.3	15.9 ± 12.7	3.8 ± 3.0	0.7 ± 0.9	142.0	120.9	58.7	10.7	45.8	11.5	5.5
SJV	FSF	174	25.7 ± 26.4	26.6 ± 23.9	7.9 ± 11.0	2.1 ± 1.1	13.3 ± 11.7	1.9 ± 2.3	0.8 ± 0.9	128.7	112.4	50.8	7.4	57.1	10.3	9.7
SJV	FREM	71	34.8 ± 42.7	37.1 ± 34.4	12.0 ± 16.2	2.2 ± 1.2	16.9 ± 14.5	4.3 ± 3.4	0.9 ± 0.9	176.0	146.9	65.4	9.1	58.8	14.2	5.3
SJV	FEDL	47	35.1 ± 24.6	32.1 ± 20.5	15.0 ± 16.7	2.4 ± 1.0	9.7 ± 4.4	2.1 ± 1.1	2.3 ± 2.7	125.7	112.8	83.8	5.5	19.3	4.7	10.5
SJV	HELM	71	16.0 ± 18.8	19.6 ± 15.4	9.8 ± 12.4	1.8 ± 0.9	5.4 ± 3.3	1.5 ± 0.9	0.6 ± 0.8	83.5	85.3	61.1	4.3	14.7	4.2	4.6
SJV	SELM	81	27.9 ± 29.5	29.5 ± 24.7	13.8 ± 17.7	2.3 ± 1.1	9.4 ± 5.6	2.5 ± 1.4	0.9 ± 1.0	127.9	106.6	76.7	6.3	27.3	6.2	4.8
SJV	VCS	78	33.1 ± 33.8	32.7 ± 25.3	14.6 ± 17.6	2.4 ± 1.2	11.3 ± 6.0	2.7 ± 1.6	1.1 ± 1.0	130.0	110.8	73.9	6.7	27.2	8.5	4.5
SJV	COP	78	28.4 ± 32.0	29.2 ± 26.3	14.7 ± 19.8	2.2 ± 1.2	8.6 ± 5.0	2.1 ± 1.3	1.1 ± 1.1	145.0	121.5	89.9	6.0	26.5	5.8	5.7
SJV	ANGI	73	28.3 ± 28.0	27.1 ± 24.0	14.0 ± 17.8	2.3 ± 1.3	6.9 ± 4.7	1.2 ± 1.0	2.3 ± 1.9	123.4	104.7	78.3	6.3	21.9	4.2	7.7
SJV	PIXL	74	29.4 ± 34.7	29.1 ± 26.2	16.9 ± 22.2	2.4 ± 1.2	6.7 ± 3.5	1.7 ± 0.9	0.9 ± 1.0	164.9	125.2	100.3	5.8	15.5	3.8	6.0
SJV	OLD	59	24.5 ± 30.8	28.0 ± 23.9	13.3 ± 19.0	2.5 ± 1.3	8.8 ± 4.1	1.9 ± 0.9	1.0 ± 1.2	140.6	98.1	73.2	7.0	20.6	4.3	6.2
SJV	BRES	53	42.4 ± 43.5	42.3 ± 36.5	19.9 ± 24.8	2.7 ± 1.6	14.1 ± 8.3	3.8 ± 2.4	1.1 ± 1.1	158.9	166.2	107.9	7.4	36.3	9.8	5.8
SJV	BAC	74	31.4 ± 28.8	32.3 ± 27.8	13.0 ± 18.4	2.6 ± 1.4	11.5 ± 7.6	2.4 ± 1.9	2.3 ± 3.1	132.7	131.5	78.0	7.8	33.7	8.8	22.9
SJV	FEL	71	17.8 ± 21.5	19.7 ± 16.5	9.7 ± 13.7	2.1 ± 1.0	5.4 ± 3.0	1.0 ± 0.6	1.2 ± 1.5	113.1	85.3	62.1	6.8	11.9	2.4	6.0
SJV	FELF	72	16.6 ± 19.3	19.1 ± 15.5	9.8 ± 13.3	2.3 ± 1.2	5.3 ± 2.9	0.9 ± 0.5	0.5 ± 0.8	82.8	86.1	64.6	9.2	12.3	2.2	5.4
SJV	EDW	44	5.8 ± 3.6	8.8 ± 5.1	1.4 ± 1.4	1.6 ± 1.0	4.0 ± 3.2	0.8 ± 0.6	0.6 ± 1.0	16.9	22.7	7.5	4.4	10.7	3.0	6.0
SV	SDP	96	14.1 ± 15.5	15.4 ± 14.3	3.0 ± 4.9	1.6 ± 0.9	9.1 ± 9.4	0.8 ± 0.8	0.4 ± 0.2	114.0	102.2	30.2	5.7	63.8	4.5	1.0
SV	S13	75	16.6 ± 18.8	19.9 ± 15.7	5.8 ± 8.2	1.6 ± 1.3	8.6 ± 6.4	2.7 ± 2.3	0.5 ± 0.7	90.2	77.8	53.3	9.8	30.7	13.4	4.2

**Table 6-4 Statistical summary of major PM<sub>2.5</sub> species collected at selected urban sites between 12/1/99 and 2/18/01. (Based on 50 days with matching data)**

Site	Concentrations (µg/m <sup>3</sup> )				Percentiles (µg/m <sup>3</sup> )			COV	Obs
ID	Mean	SD	Minimum	Maximum	25th	50th	75th	%	Count
<b>Ammonium Nitrate</b>									
SOH	5.0	6.5	0.3	24.7	1.1	2.2	5.1	129	50
M14	6.5	7.6	0.6	34.5	1.9	3.6	7.8	118	50
MRM	7.9	9.7	0.8	35.6	1.7	3.8	9.6	123	50
CLO	10.0	12.3	0.7	48.9	2.1	4.3	10.9	124	50
FSF	9.3	12.5	0.2	50.8	1.3	4.3	11.6	134	50
VCS	12.4	14.4	0.7	53.2	3.2	5.7	15.8	116	50
COP	11.1	13.5	0.0	57.3	2.5	5.3	15.8	122	50
BAC	12.0	17.7	0.4	76.6	1.5	4.1	15.3	147	50
<b>Carbonaceous aerosols</b>									
SOH	9.9	6.1	0.5	26.9	4.8	8.8	14.1	62	50
M14	12.1	8.3	1.6	38.0	6.1	9.6	15.2	69	50
MRM	12.1	8.8	2.1	36.8	6.4	9.1	14.6	73	50
CLO	13.0	7.8	3.4	32.2	7.2	10.4	17.8	60	50
FSF	17.9	16.0	3.5	59.7	7.6	10.1	23.2	89	50
VCS	12.5	6.5	2.2	33.6	8.0	11.5	15.4	52	50
COP	9.6	6.0	0.9	32.2	5.4	8.7	13.0	62	50
BAC	13.2	8.5	3.7	40.5	7.5	9.5	16.0	65	50
<b>Ammonium Sulfate</b>									
SOH	1.6	0.9	0.0	4.0	0.9	1.5	2.0	57	50
M14	1.8	0.9	0.5	5.1	1.1	1.6	2.1	51	50
MRM	1.6	0.8	0.3	3.9	1.1	1.4	2.0	47	50
CLO	1.9	1.0	0.3	6.5	1.2	1.7	2.3	51	50
FSF	1.9	1.1	0.3	7.2	1.3	1.8	2.3	55	50
VCS	2.3	1.2	0.4	6.7	1.6	2.2	2.8	51	50
COP	2.0	1.1	0.0	5.7	1.3	1.7	2.6	54	50
BAC	2.5	1.2	0.6	6.0	1.4	2.5	3.1	50	50

**Table 6-5 Statistical summary of major PM<sub>2.5</sub> species collected at Fresno and Bakersfield between 12/1/99 and 2/18/01. (Based on 70 days with matching data)**

Site	Concentrations (µg/m <sup>3</sup> )				Percentiles (µg/m <sup>3</sup> )			COV	Obs
ID	Mean	SD	Minimum	Maximum	25th	50th	75th	%	Count
<b>Ammonium Nitrate</b>									
BAC	11.9	17.1	0.2	76.6	1.4	3.7	15.3	143	70
FSF	9.5	12.4	0.2	50.8	1.5	4.3	11.7	131	70
<b>Carbonaceous aerosols</b>									
BAC	13.3	8.9	3.7	40.5	7.3	9.4	16.0	67	70
FSF	18.4	17.2	3.5	73.9	7.2	9.9	23.2	94	70
<b>Ammonium Sulfate</b>									
BAC	2.6	1.2	0.6	6.0	1.5	2.7	3.2	48	70
FSF	2.0	1.0	0.3	7.2	1.3	1.9	2.5	52	70

**Table 6-6 Statistical summary of major PM<sub>2.5</sub> species collected at selected rural/intrabasin sites between 12/1/99 and 2/18/01.  
(Based on 66 days with matching data)**

Site	Concentrations (µg/m <sup>3</sup> )				Percentiles (µg/m <sup>3</sup> )			COV	Obs
ID	Mean	SD	Minimum	Maximum	25th	50th	75th	%	Count
<b>Ammonium Nitrate</b>									
SWC	8.5	9.4	0.5	36.7	2.1	4.4	11.0	110	66
HELM	10.0	12.7	0.7	61.1	1.9	3.8	13.5	127	66
SELM	13.1	16.7	0.6	76.7	2.0	6.2	17.1	127	66
PIXL	14.8	19.9	0.4	100.3	2.2	6.0	20.2	134	66
<b>Carbonaceous aerosols</b>									
SWC	6.0	3.7	0.3	17.9	3.3	5.9	7.9	61.5	66
HELM	7.0	4.2	0.1	18.9	3.9	6.7	9.2	59.8	66
SELM	11.4	6.2	1.2	27.7	7.5	10.2	14.5	53.8	66
PIXL	7.9	3.8	0.1	16.4	4.6	7.8	10.5	48.5	66
<b>Ammonium Sulfate</b>									
SWC	1.6	0.7	0.4	3.5	1.1	1.4	2.1	45.3	66
HELM	1.9	0.9	0.3	4.3	1.2	1.7	2.5	49.5	66
SELM	2.4	1.1	0.7	6.3	1.6	2.2	2.8	47.5	66
PIXL	2.3	1.2	0.5	5.8	1.5	2.1	3.0	51.1	66

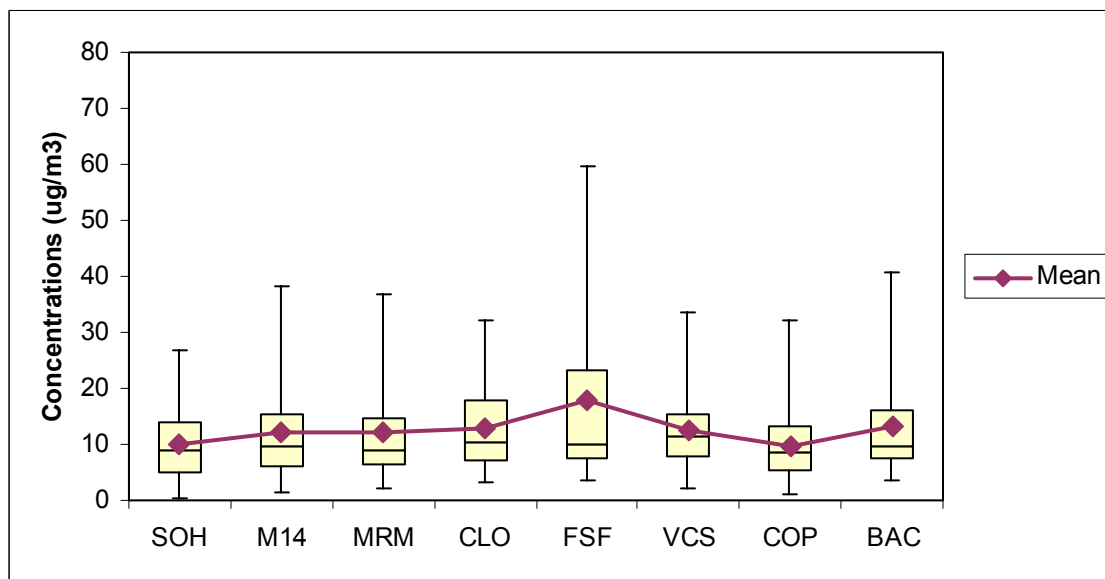
**Table 6-7 Statistical summary of major PM<sub>2.5</sub> species collected at selected rural/interbasin sites between 12/1/99 and 2/18/01.  
(Based on 69 days with matching data)**

Site	Concentrations (µg/m <sup>3</sup> )				Percentiles (µg/m <sup>3</sup> )			COV	Obs
ID	Mean	SD	Minimum	Maximum	25th	50th	75th	%	Count
<b>Ammonium Nitrate</b>									
SNFH	4.6	6.6	0.2	28.4	0.8	1.5	5.1	144	69
FEL	10.2	14.0	0.0	62.1	1.0	3.0	14.8	137	69
FELF	10.6	13.8	0.3	64.6	1.2	2.9	15.8	131	69
<b>Carbonaceous aerosols</b>									
SNFH	8.8	4.3	1.4	21.8	5.5	7.9	11.2	48	69
FEL	6.9	4.2	0.0	22.9	4.5	6.4	9.6	61	69
FELF	6.4	3.4	0.2	13.8	3.5	6.3	8.7	53	69
<b>Ammonium Sulfate</b>									
SNFH	1.5	0.8	0.2	3.8	0.8	1.4	1.9	53	69
FEL	2.2	1.3	0.2	7.6	1.4	2.1	2.6	57	69
FELF	2.3	1.3	0.5	9.2	1.4	2.1	2.6	57	69

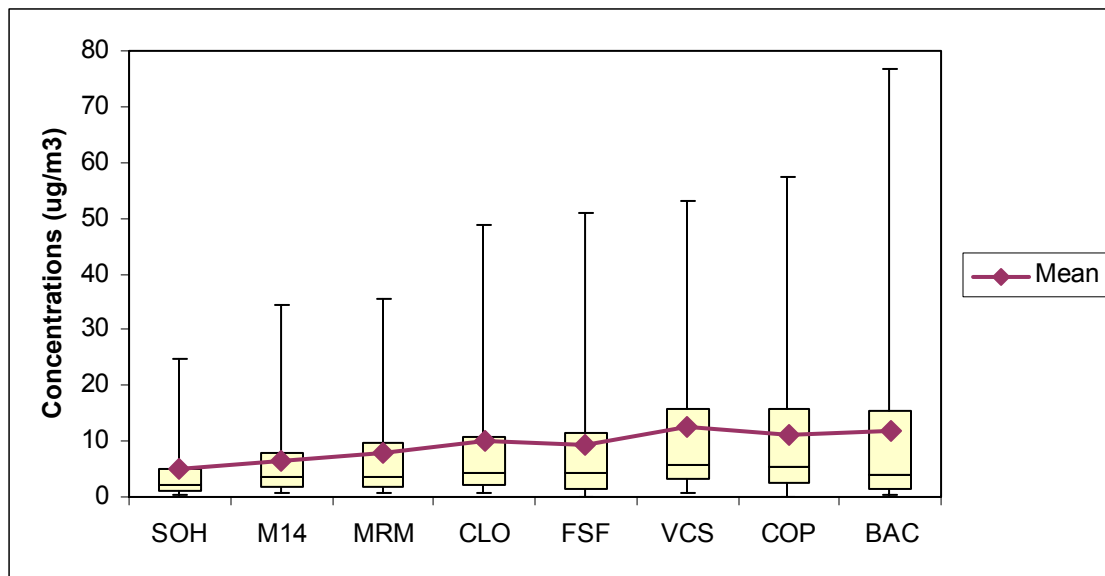
**Table 6-8 Summary of major PM<sub>2.5</sub> chemical species summarized by site type.  
(Based on 35 Days with Matching Data)**

Site ID	Concentrations (µg/m³)				Percentiles (µg/m³)			COV %	Obs Count
	Mean	SD	Minimum	Maximum	25th	50th	75th		
Ammonium Nitrate									
Urban	11.1	13.5	0.4	76.6	2.0	4.5	17.1	122	280
Rural/Intrabasin	11.3	12.4	0.4	68.9	2.7	5.9	16.9	110	140
Rural/Interbasin	8.5	12.2	0.0	57.4	1.2	1.9	12.1	144	105
Carbonaceous aerosols									
Urban	14.1	9.8	0.5	59.7	8.1	11.1	17.4	69	280
Rural/Intrabasin	8.1	4.5	0.3	25.2	4.5	7.7	10.4	56	140
Rural/Interbasin	6.9	4.0	0.2	21.8	4.8	6.7	9.8	58	105
Ammonium Sulfate									
Urban	2.0	0.9	0.0	6.0	1.3	1.9	2.5	47	280
Rural/Intrabasin	1.8	0.9	0.4	5.8	1.2	1.7	2.3	47	140
Rural/Interbasin	1.8	0.9	0.4	4.7	1.3	1.6	2.5	49	105

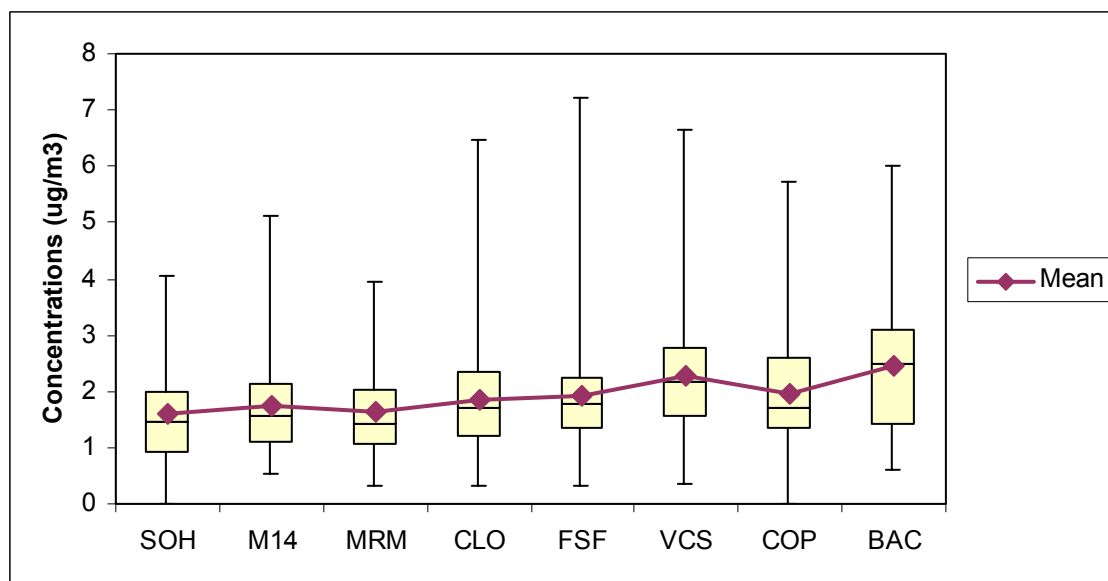
**Figure 6-10 PM<sub>2.5</sub> carbonaceous aerosols concentrations at urban sites between 12/1/99 and 2/18/01. (Based on 50 days with matching data)**



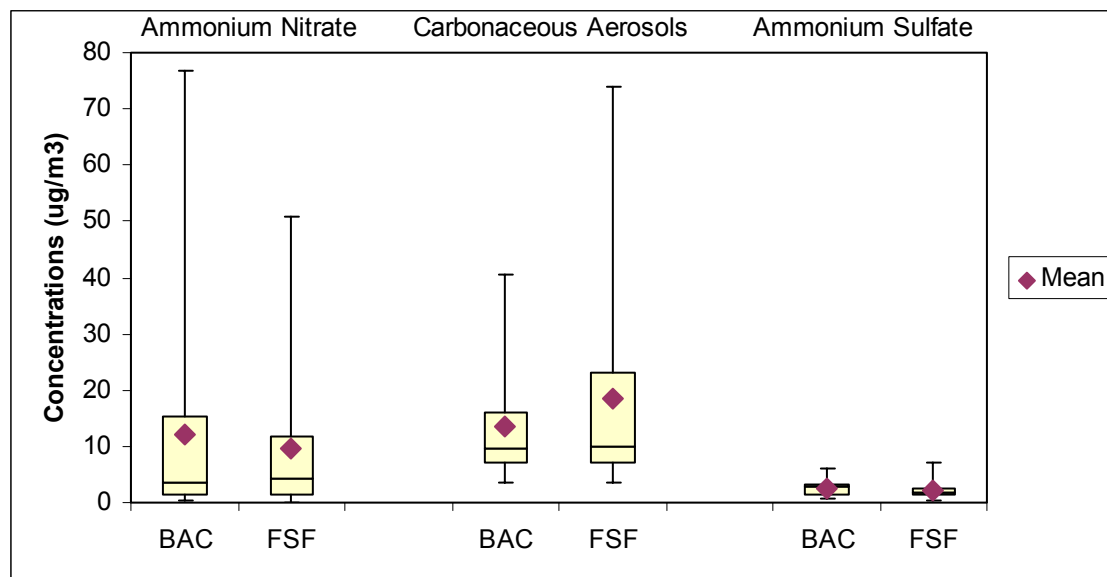
**Figure 6-11 PM<sub>2.5</sub> ammonium nitrate concentrations at urban sites between 12/1/99 and 2/18/01. (Based on 50 days with matching data)**



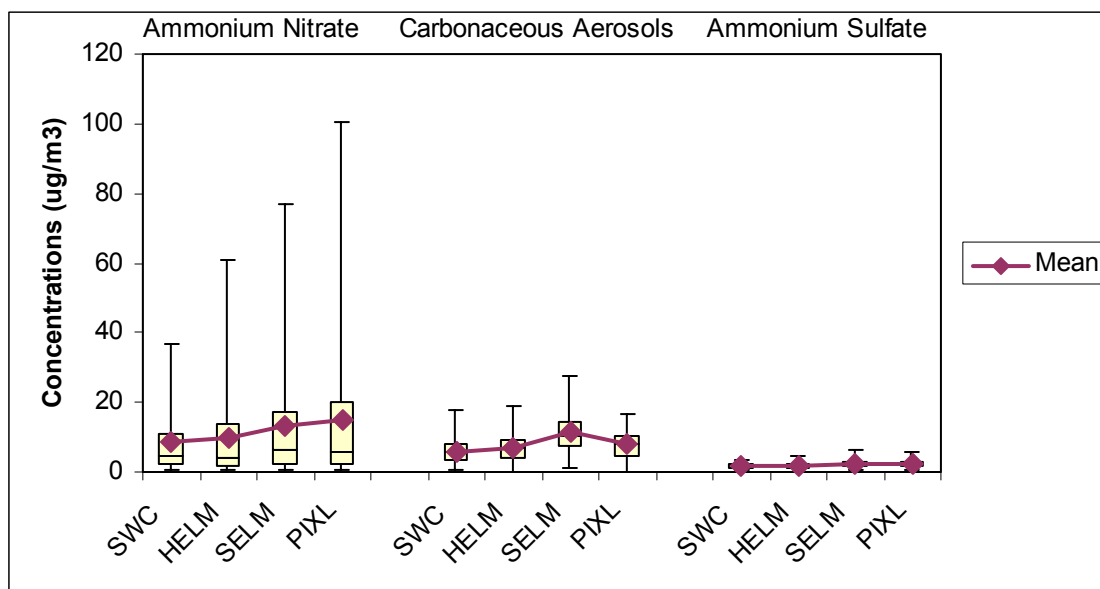
**Figure 6-12 PM<sub>2.5</sub> ammonium sulfate concentrations at urban sites between 12/1/99 and 2/18/01. (Based on 50 days with matching data)**



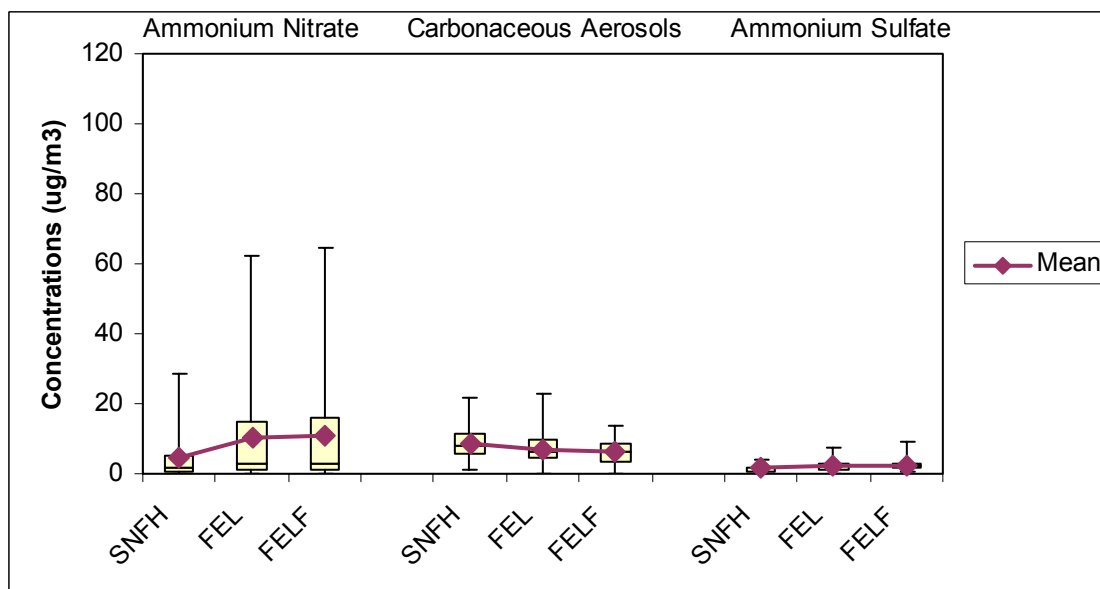
**Figure 6-13 Comparison of major PM<sub>2.5</sub> species at Bakersfield and Fresno between 12/1/99 and 2/18/01. (Based on 70 days with matching data)**



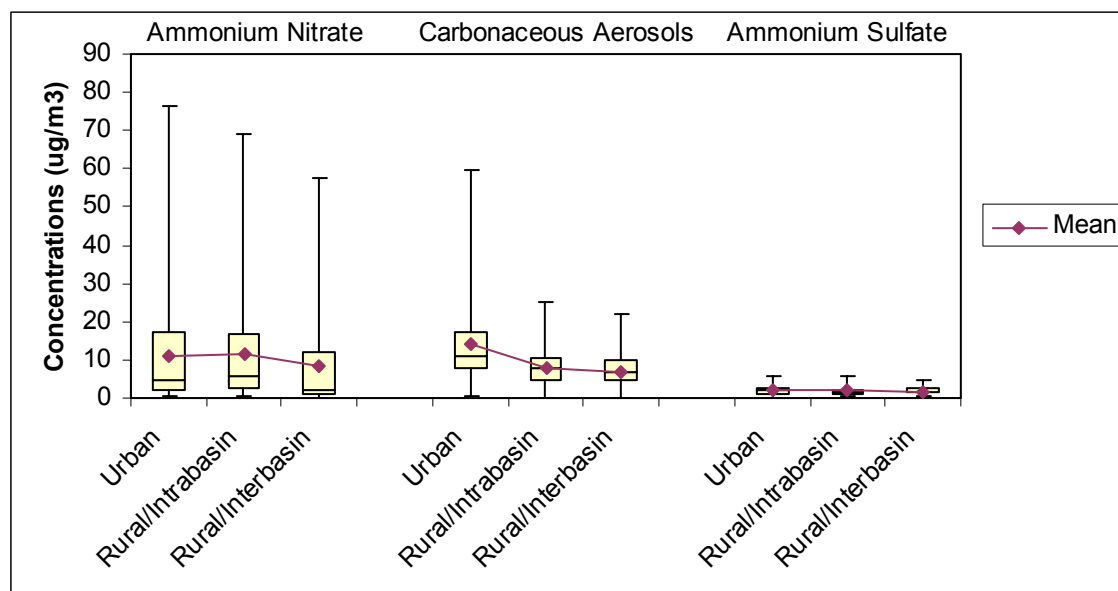
**Figure 6-14 Major PM<sub>2.5</sub> species at rural/intrabasin sites between 12/1/99 and 2/18/01. (Based on 66 days with matching data)**



**Figure 6-15 Major PM<sub>2.5</sub> species at rural/interbasin sites between 12/2/99 and 2/6/01. (Based on 66 days with matching data)**



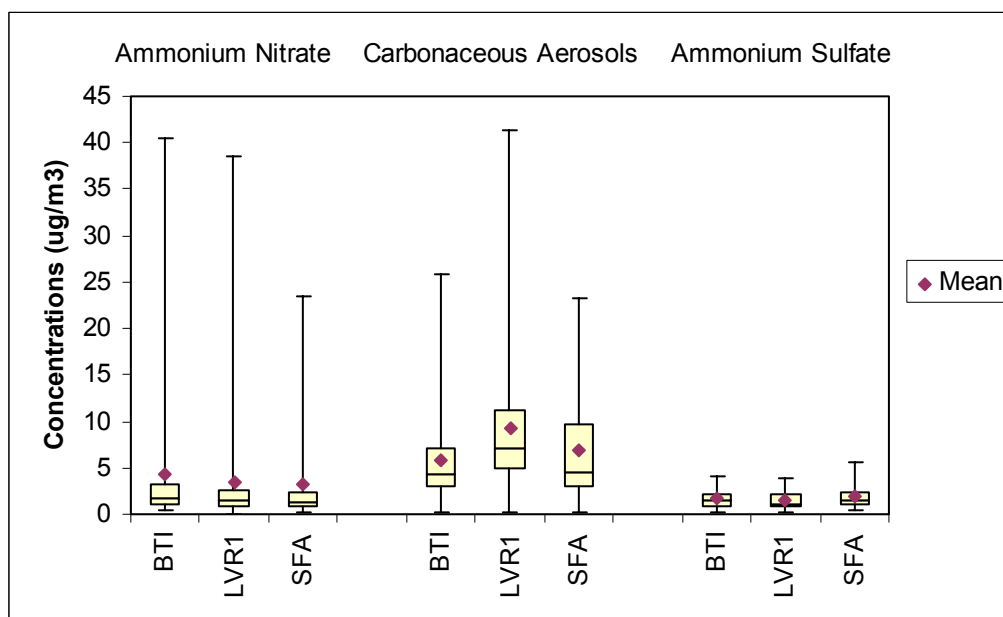
**Figure 6-16 Comparison of major PM<sub>2.5</sub> chemical species by site type.**  
**(Based on 35 days with matching data)**



### 6.3.1.1 PM<sub>2.5</sub> Chemical Components in the San Francisco Bay Area

During CRPAQS three monitoring sites in the San Francisco Bay Area Air Basin (Bethel Island, Livermore-793 Rincon Avenue, and San Francisco-Arkansas) had matching PM<sub>2.5</sub> chemical composition data for 69 days. Based on the average for these days, PM<sub>2.5</sub> mass at each site was dominated by carbonaceous aerosols. However, the magnitude of carbonaceous aerosols concentrations differed significantly from site to site (Figure 6-17). Livermore, with an average carbonaceous aerosols concentration of 9.2 µg/m<sup>3</sup> and a peak of 41 µg/m<sup>3</sup>, was the highest site. The second highest site was San Francisco-Arkansas with an average carbonaceous aerosols concentration of 6.8 µg/m<sup>3</sup> and a peak of 23 µg/m<sup>3</sup>. Bethel Island site measured a carbonaceous aerosols peak slightly higher than San Francisco-Arkansas, but on average, its concentrations were about 10% lower. Ammonium nitrate was the second highest component. Average concentrations of ammonium nitrate were low and fairly uniform among the three sites (Figure 6-17). They ranged from 3.1 µg/m<sup>3</sup> at San Francisco-Arkansas to 4.3 µg/m<sup>3</sup> at Bethel Island. Peak concentrations of about 40 µg/m<sup>3</sup> were found at Bethel Island and Livermore. The next highest peak was 23 µg/m<sup>3</sup> measured at San Francisco-Arkansas. Ammonium sulfate concentrations were lower than ammonium nitrate (about 50% lower on an average and 10 times lower for peak concentrations).

**Figure 6-17 Comparison of major PM<sub>2.5</sub> species at San Francisco Bay Area sites between 12/1/99 and 2/18/01. (Based on 69 Days with Matching Data)**



### 6.3.1.2 PM<sub>2.5</sub> Chemical Components in the Sacramento Valley

Since there was not enough matching data to conduct a site-to-site comparison for the Sacramento Valley, chemical components were summarized for each monitoring site instead. On average, carbonaceous aerosols concentrations were two to three times

higher than ammonium nitrate concentrations at each of the three sites listed in Table 6-9. While average carbonaceous aerosols concentrations ranged from 8.8  $\mu\text{g}/\text{m}^3$  at Pleasant Grove to 12.7  $\mu\text{g}/\text{m}^3$  at Sacramento-Del Paso Manor, ammonium nitrate concentrations ranged from 3.9  $\mu\text{g}/\text{m}^3$  at Pleasant Grove and Sacramento-Del Paso Manor to 5.7  $\mu\text{g}/\text{m}^3$  at Sacramento-T Street. Ammonium sulfate concentrations were very low compared to the other two components and ranged from 1.5  $\mu\text{g}/\text{m}^3$  at Pleasant Grove to 1.7  $\mu\text{g}/\text{m}^3$  at Sacramento-Del Paso Manor. Peak carbonaceous aerosols concentrations were about three times higher than nitrate at Pleasant Grove and Sacramento-Del Paso Manor, but about 25% lower at Sacramento-T Street.

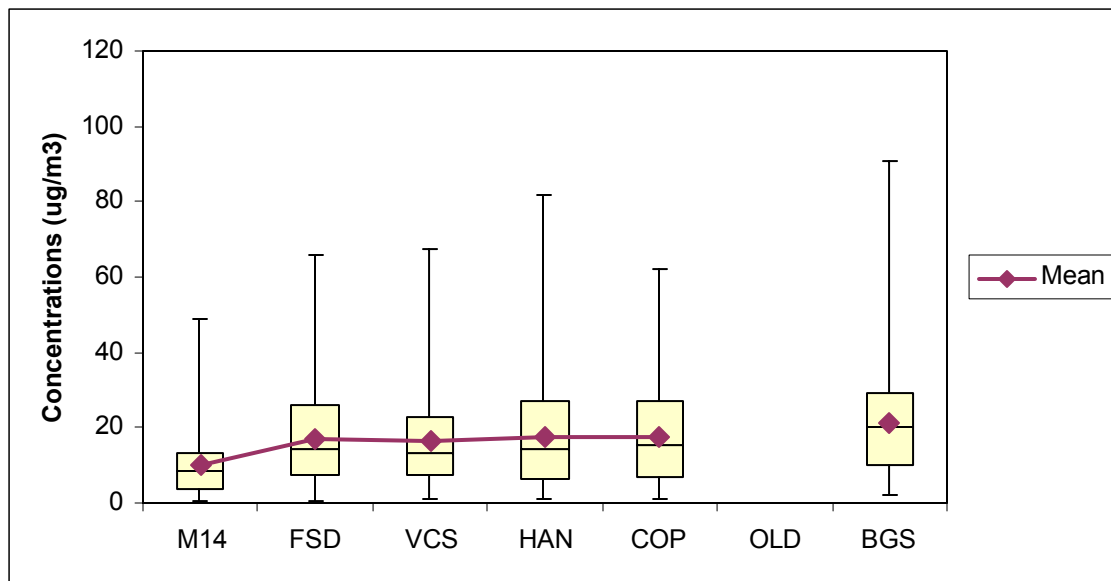
**Table 6-9 Statistical summary of major PM<sub>2.5</sub> species in the Sacramento Valley between 12/1/99 and 2/18/01.**

Monitoring Site/ Chemical Component	Concentrations (µg/m³)				Percentiles (µg/m³)			COV %	Obs Count
	Mean	SD	Minimum	Maximum	25th	50th	75th		
Pleasant Grove									
Ammonium Nitrate	3.9	6.1	0.2	38.8	1.0	1.6	4.2	157	64
Carbonaceous aerosols	8.8	12.1	0.3	94.3	3.6	6.6	9.3	138	64
Ammonium Sulfate	1.5	1.0	0.2	6.5	0.7	1.2	1.9	71	64
Sacramento-T Street									
Ammonium Nitrate	5.7	8.2	0.3	53.3	1.0	2.3	8.1	144	77
Carbonaceous aerosols	11.2	8.4	1.7	39.4	4.9	8.0	15.4	75	77
Ammonium Sulfate	1.6	1.2	0.3	9.8	0.9	1.2	1.8	80	77
Sacramento-Del Paso Manor									
Ammonium Nitrate	3.9	6.4	0.0	30.2	0.7	1.4	3.0	166	42
Carbonaceous aerosols	12.7	17.0	2.7	86.2	4.6	6.0	11.9	134	43
Ammonium Sulfate	1.7	0.9	0.1	4.1	1.0	1.5	2.0	54	42

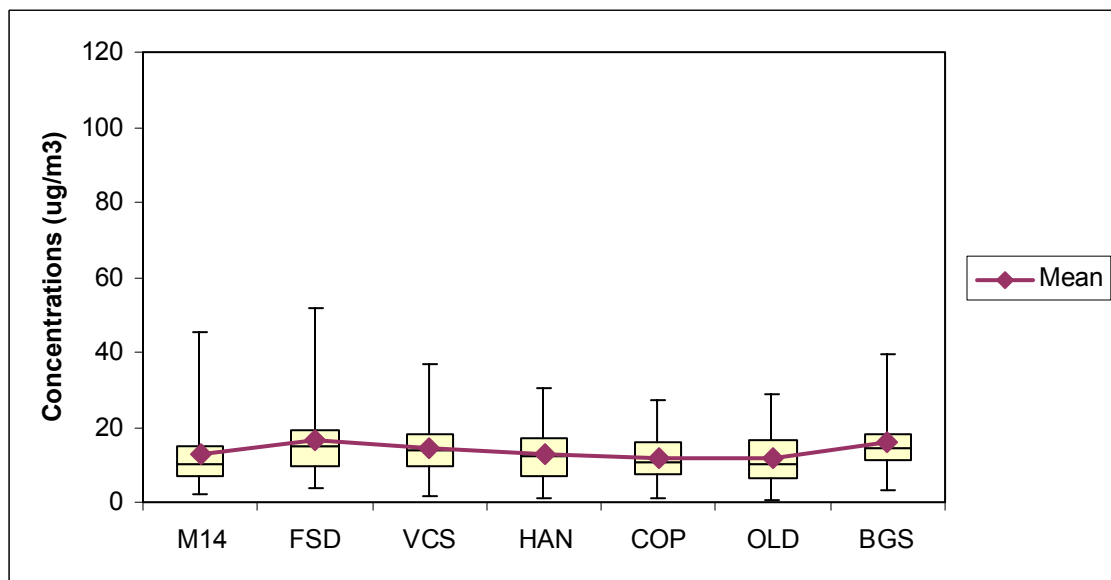
### 6.3.2 PM<sub>10</sub> Chemical Components

The PM<sub>10</sub> chemical composition data were compared for the seven San Joaquin Valley sites shown in Figure 6-18 through Figure 6-20. Analysis of geological material excluded Oildale because data was missing on several peak days. On average, geological material was a leading component of the PM<sub>10</sub> mass, followed by carbonaceous aerosols and ammonium nitrate. The average concentration of geological material, for the six sites shown in Figure 6-18, was 16.7  $\mu\text{g}/\text{m}^3$ . Highest concentrations were found at Bakersfield-Golden (an average of 21.4  $\mu\text{g}/\text{m}^3$  and a peak of 91  $\mu\text{g}/\text{m}^3$ ). Lowest concentrations, an average of 10.2  $\mu\text{g}/\text{m}^3$  and a peak of 49  $\mu\text{g}/\text{m}^3$ , were measured at Modesto in the northern San Joaquin Valley. The central portion of the Valley had fairly uniform concentrations with an average ranging from 16.4  $\mu\text{g}/\text{m}^3$  at Visalia to 17.8  $\mu\text{g}/\text{m}^3$  at Hanford and peaks from 62  $\mu\text{g}/\text{m}^3$  at Corcoran to 82  $\mu\text{g}/\text{m}^3$  at Hanford. Carbonaceous aerosols, with a 13.8  $\mu\text{g}/\text{m}^3$  average for the seven sites, were the second leading component (Figure 6-19). Carbonaceous aerosols concentrations were highest at Fresno-Drummond (an average of 16.7  $\mu\text{g}/\text{m}^3$  and a peak of 52  $\mu\text{g}/\text{m}^3$ ); followed by Bakersfield-Golden, with an average concentration of 15.9  $\mu\text{g}/\text{m}^3$  and a peak of 39  $\mu\text{g}/\text{m}^3$ . Ammonium nitrate concentrations were only slightly lower than carbon, increasing from north to south (Figure 6-20). The average concentration ranged from 8.9  $\mu\text{g}/\text{m}^3$  at Modesto to 17.5  $\mu\text{g}/\text{m}^3$  at Oildale and the peak from about 50  $\mu\text{g}/\text{m}^3$  at Modesto to 112  $\mu\text{g}/\text{m}^3$  at Oildale.

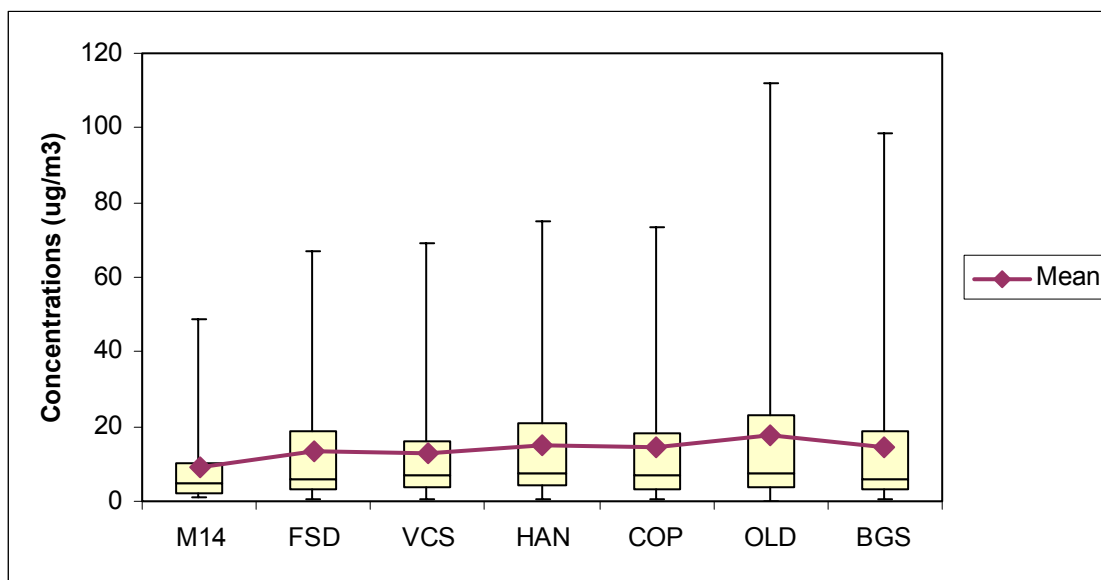
**Figure 6-18 PM<sub>10</sub> geological material concentrations between 12/2/99 and 2/6/01. (Based on 48 days with matching data)**



**Figure 6-19 PM<sub>10</sub> carbonaceous aerosols concentrations between 12/2/99 and 2/6/01. (Based on 48 days with matching data)**



**Figure 6-20 PM<sub>10</sub> ammonium nitrate concentrations between 12/2/99 and 2/6/01.  
(Based on 49 days with matching data)**



## 7 VARIABILITY DURING AN EPISODE

Data variability during an episode was analyzed using data for the two most severe episodes: December 1999 and December 2000. The analysis was based, to the extent possible, on matching data for each monitoring site within an air basin, except for the San Joaquin Valley where matching was done for each site type, e.g. urban, rural/intrabasin, and rural/interbasin.

### 7.1 PM<sub>2.5</sub> Concentrations

This section examines the spatial and temporal distribution of PM<sub>2.5</sub> concentrations during the December 1999 and December 2000 episodes.

#### 7.1.1 PM<sub>2.5</sub> Site-to-Site Variations

The site-averaged concentrations for the December 1999 episode were calculated based on four days with matching data collected between December 18, 1999 and January 1, 2000 (Table 7-1). The monitoring site at Fresno-1<sup>st</sup> Street had the highest concentrations among the nine urban sites (Figure 7-1). It had an average concentration of 91 µg/m<sup>3</sup> and a peak of 127 µg/m<sup>3</sup>. Concentrations decreased gradually away from Fresno. Both urban and rural sites had similar spatial patterns. The highest rural/intrabasin site, Selma, located 15 miles south-southeast of Fresno, had an average concentration of 84 µg/m<sup>3</sup> (Figure 7-1). This was almost as high as the urban peak and significantly higher than the other rural sites. The rural/interbasin sites had concentrations

even lower than the lowest sites in the other two groups (Table 7-8). Average site concentrations in the San Francisco Bay Area ranged from 14  $\mu\text{g}/\text{m}^3$  at Concord to 47  $\mu\text{g}/\text{m}^3$  at Vallejo (Table 7-3). Concentrations in San Francisco and San Jose were in the 20-30  $\mu\text{g}/\text{m}^3$  range. Sacramento Valley concentrations were markedly higher and ranged from 17  $\mu\text{g}/\text{m}^3$  at Redding to 65  $\mu\text{g}/\text{m}^3$  at Sacramento-Del Paso Manor (Table 7-4).

Concentration patterns were very different during the December 2000 episode. The site-averaged concentrations in the San Joaquin Valley were based on 11 days with matching data collected between December 18, 1999 and January 7, 2001 (Table 7-2). The two major urban areas, Fresno and Bakersfield, had equally high concentrations of almost 95  $\mu\text{g}/\text{m}^3$  (Figure 7-2). Concentrations in the northern Valley were significantly lower, ranging from 53  $\mu\text{g}/\text{m}^3$  at Stockton to 72  $\mu\text{g}/\text{m}^3$  at Modesto. Rural/intrabasin sites showed increases from north to south but even the highest rural site, Pixley with 76  $\mu\text{g}/\text{m}^3$ , was significantly lower than the peak urban site. Once again, concentrations at rural/interbasin sites were significantly lower than the other two groups. The San Francisco Bay Area and Sacramento Valley Air Basins had fewer days with matching data, as indicated in Table 7-4 and Table 7-6. Concentrations in the San Francisco Bay Area were much higher than the December 1999 episode (Table 7-4). The Bodega Marine Lab monitoring site, with an average concentration of 18  $\mu\text{g}/\text{m}^3$  was the lowest site and Vallejo with 52  $\mu\text{g}/\text{m}^3$  was the highest. Most sites had average concentrations above 40  $\mu\text{g}/\text{m}^3$ . Sacramento Valley experienced concentrations similar to the December 1999 episode, except at Sacramento-Del Paso Manor which measured 120  $\mu\text{g}/\text{m}^3$  on January 1, 2001 (Table 7-6).

During the course of an episode each site experienced a wide variability in concentrations reflected in high coefficient of variations (site-averaged COV). Several factors affected data variability at a site. The more urban and centrally located the site was, the less variable were the  $\text{PM}_{2.5}$  concentrations. For example, Fresno with its central location within the Valley and urban character, had the least variability in the data (32% coefficient of variation) during both episodes (Table 7-1 and Table 7-2). Bakersfield, despite urban character, had more variability because, due to more distant location in the southern portion of the Valley, it was less impacted by the dispersion of pollution throughout the Valley. Corcoran, with a semi-rural character, also had more variable concentrations compared to other urban sites. The two most peripherally located urban sites, Stockton to the north and Edison to the south, had the most variable concentrations. During the December 1999 episode Stockton had a 76% coefficient of variation while all other urban sites ranged from 32% to 59%. During the December 2000 episode, Edison had 61% coefficient of variation while the other sites ranged from 32% to 57%. Rural sites exhibited even more variation in concentrations. The average rural site had a 70% coefficient of variation for the December 1999 episode (Table 7-7) and 56% for the December 2000 episode (Table 7-8). Higher variability during the first episode may simply be an artifact of having fewer data points.

Variability changed dramatically from site-to-site and from episode-to-episode in the San Francisco Bay Area, ranging from less than 20% to almost 100% (Table 7-3 and Table 7-4). The Sacramento Valley Air Basin had about a 50% coefficient of variation in the

Sacramento urban area (Table 7-5 and Table 7-6). Concentrations in the outlying areas were much more uniform during the December 1999 episode than during the December 2000 episode.

### 7.1.2 **PM<sub>2.5</sub> Day-to-Day Variations**

Day-to-day changes in daily average concentrations reflect the rate of pollution buildup. During the December 1999 episode, concentrations started out low for all three types of sites: urban, rural/intrabasin, and rural interbasin. On December 14, 1999, an average site had PM<sub>2.5</sub> concentrations below 30 µg/m<sup>3</sup> (Figure 7-3). However, concentrations built up so rapidly that only six days later, on December 20, 1999, the average concentration for nine urban sites exceeded 100 µg/m<sup>3</sup>. Average for the four rural/intrabasin sites was only about 20 µg/m<sup>3</sup> lower, at 78 µg/m<sup>3</sup>. Rural/interbasin sites with an average of 36 µg/m<sup>3</sup> were trailing far behind the other two site types. After another six days, on December 26, 1999, the rural/intrabasin sites had the highest average of about 104 µg/m<sup>3</sup>, followed by the urban sites with 86 µg/m<sup>3</sup>. Rural/interbasin sites were still much lower. At the end of the episode, on January 1, 2000, all three groups showed similar average concentrations. However, within an urban group concentrations showed a strong dichotomy. As shown in Figure 7-5, concentrations were clustered in two groups; they were high in the Central San Joaquin Valley and moderate in the rest of the Valley.

During the December 2000 episode, concentrations also started low but the buildup rate was much slower. Unlike the December 1999 episode when only six days into the episode concentrations reached their peak, this time it took 20 days for concentrations to reach their peak. Daily-average urban concentrations increased from 31.1 µg/m<sup>3</sup> at the beginning of the episode (December 18, 2000) to 117 µg/m<sup>3</sup> towards the end of the episode (January 6, 2001) (Figure 7-4). Rural/intrabasin concentrations started out lower, at 17 µg/m<sup>3</sup>, but by January 6, 2001 were as high as urban concentrations. Rural/interbasin concentrations were significantly lower and remained below 60 µg/m<sup>3</sup> throughout the duration of the episode.

A winter type episode in the San Joaquin Valley is usually driven by large-scale meteorology. Often times the entire Valley experiences similar meteorology. Data variability changes as the episode progresses and weather changes. At the beginning of the episode concentrations are more variable because there has not been enough time for transporting pollution across large distances giving local emissions and variations in meteorology. As the episode progresses, not only does the meteorology become more uniform, but pollution disperses over larger areas and subsequently concentrations become more uniform. Both December episodes achieved remarkably uniform concentrations with 15% coefficient of variation for the nine urban sites. In the case of December 1999 episode, the most uniform concentrations, ranging from 71 µg/m<sup>3</sup> to 107 µg/m<sup>3</sup>, were captured on December 26, 1999 (Table 7-1). During the December 2000 episode urban concentrations were most uniform on January 6, 2001, when they ranged from 100 µg/m<sup>3</sup> to 145 µg/m<sup>3</sup> (Table 7-2). Concentrations were even more consistent among the rural/intrabasin sites with only 10% coefficient of variation. During the December 1999 episode, the date of highest rural uniformity coincided with that for urban uniformity on

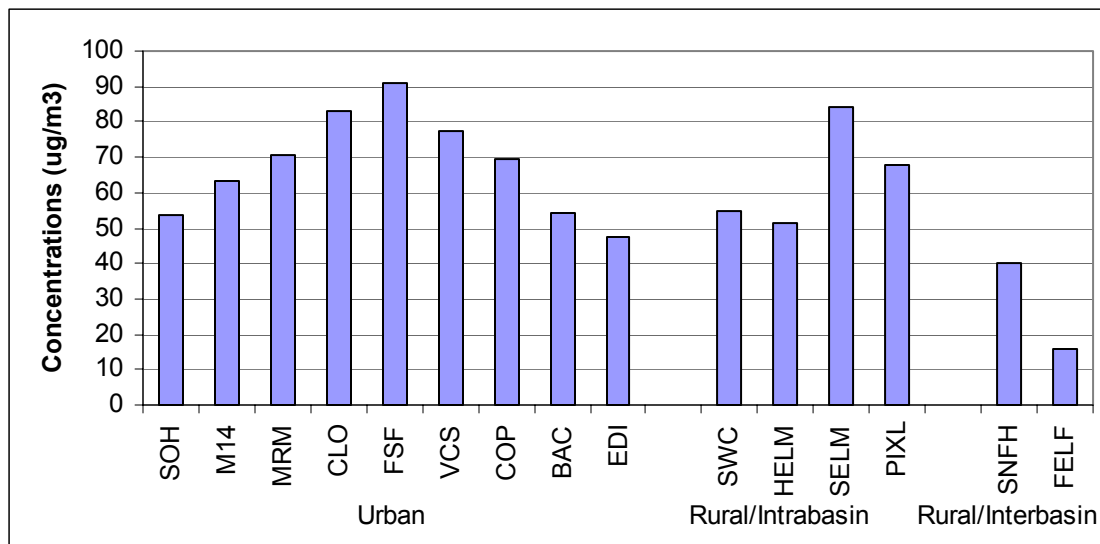
December 26 when concentrations ranged from 92  $\mu\text{g}/\text{m}^3$  to 115  $\mu\text{g}/\text{m}^3$  (Table 7-7). During the second episode, peak rural concentration uniformity lagged peak urban uniformity by a day. On January 7, 2001, rural concentrations ranged from 84  $\mu\text{g}/\text{m}^3$  to 107  $\mu\text{g}/\text{m}^3$  (Table 7-8).

### **7.1.3 Comparison of Fresno and Bakersfield**

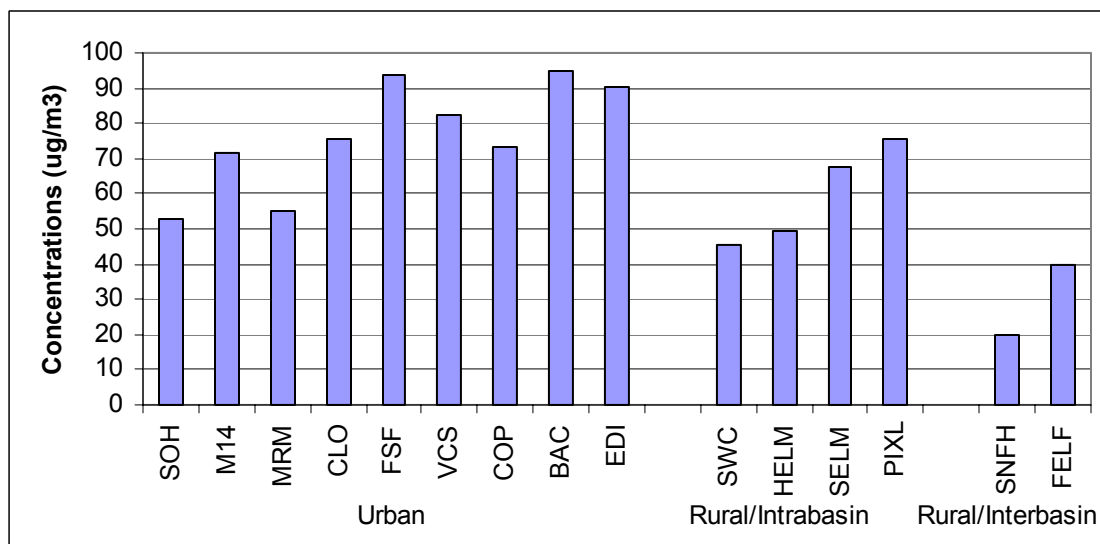
The Fresno-1<sup>st</sup> Street and Bakersfield-California monitoring sites collected daily  $\text{PM}_{2.5}$  data during both episodes. The more frequent data allows more detailed comparison among the two sites. The December 1999 episode affected the Fresno area more than Bakersfield (Figure 7-7). While both sites reached similar peak concentrations, the episode average, based on 19 days with matching data, was almost 100  $\mu\text{g}/\text{m}^3$  at Fresno but only 70  $\mu\text{g}/\text{m}^3$  at Bakersfield (Table 7-11). While Fresno had ten days with concentrations greater than 100  $\mu\text{g}/\text{m}^3$ , Bakersfield had only one (Figure 7-7).  $\text{PM}_{2.5}$  concentrations were not only higher at Fresno but also less variable. Based on the matching days, the coefficient of variation was 21% at Fresno and 33% at Bakersfield (Table 7-11).

The comparison looked quite different for the second episode in December 2000. This time, concentrations at both sites tracked each other very well, except for the last few days of the episode (Figure 7-8). The peak concentrations were slightly higher at Bakersfield (155  $\mu\text{g}/\text{m}^3$ ) than at Fresno (148  $\mu\text{g}/\text{m}^3$ ), but both sites had the same average concentration of 84  $\mu\text{g}/\text{m}^3$  (Table 7-11). Each site had seven days with concentrations greater than 100  $\mu\text{g}/\text{m}^3$ . The coefficient of variation was once again lower at Fresno but the difference was much smaller (39% compared to 45% at Bakersfield).

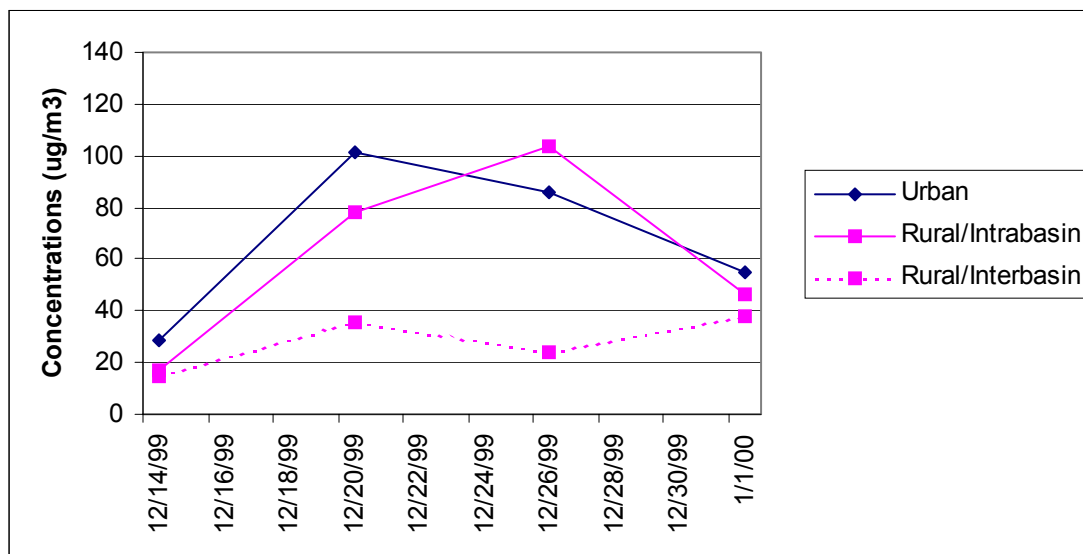
**Figure 7-1 Site-averaged PM<sub>2.5</sub> concentrations for the December 1999 episode.**



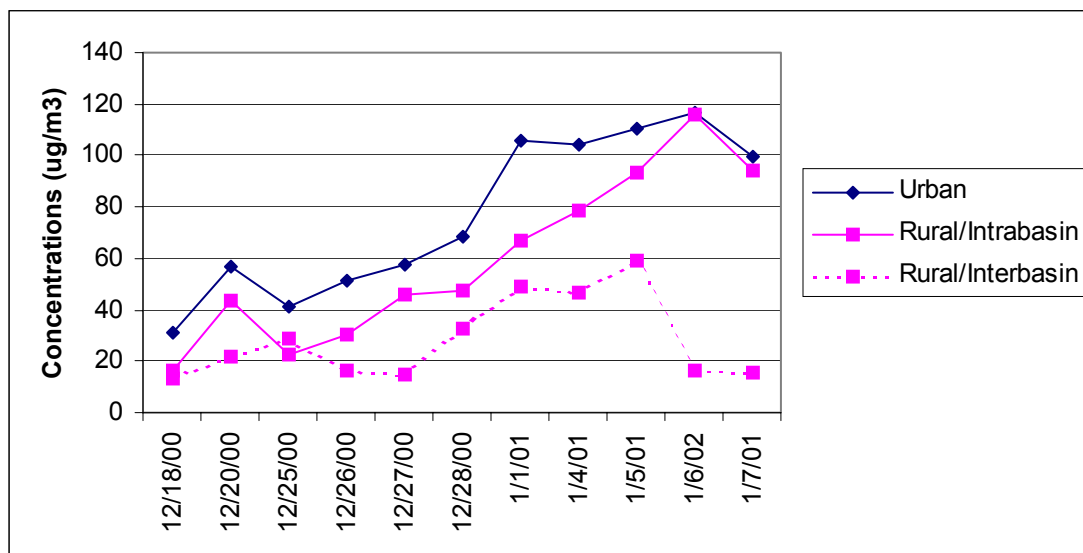
**Figure 7-2 Site-averaged PM<sub>2.5</sub> concentrations for the December 2000 episode.**



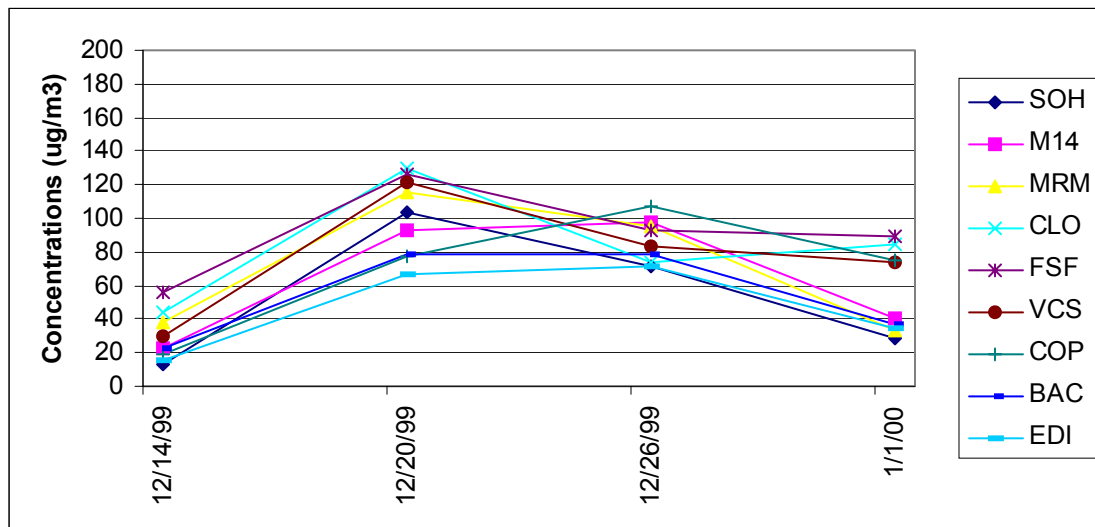
**Figure 7-3 Day-to-day variation in the average PM<sub>2.5</sub> concentrations for each site type for the December 1999 episode.**



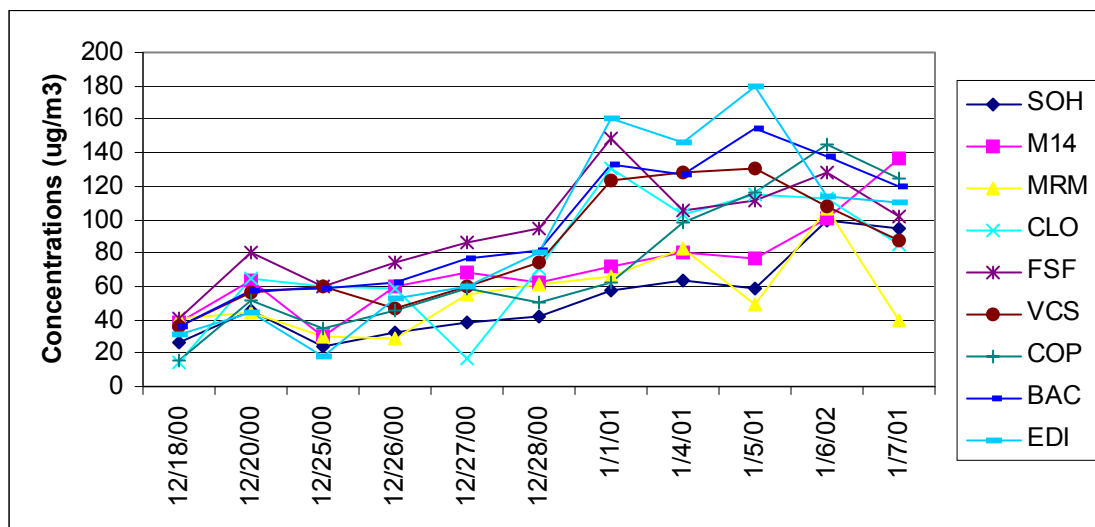
**Figure 7-4 Day-to-day variations in the average PM<sub>2.5</sub> concentrations for each site type for the December 2000 episode.**



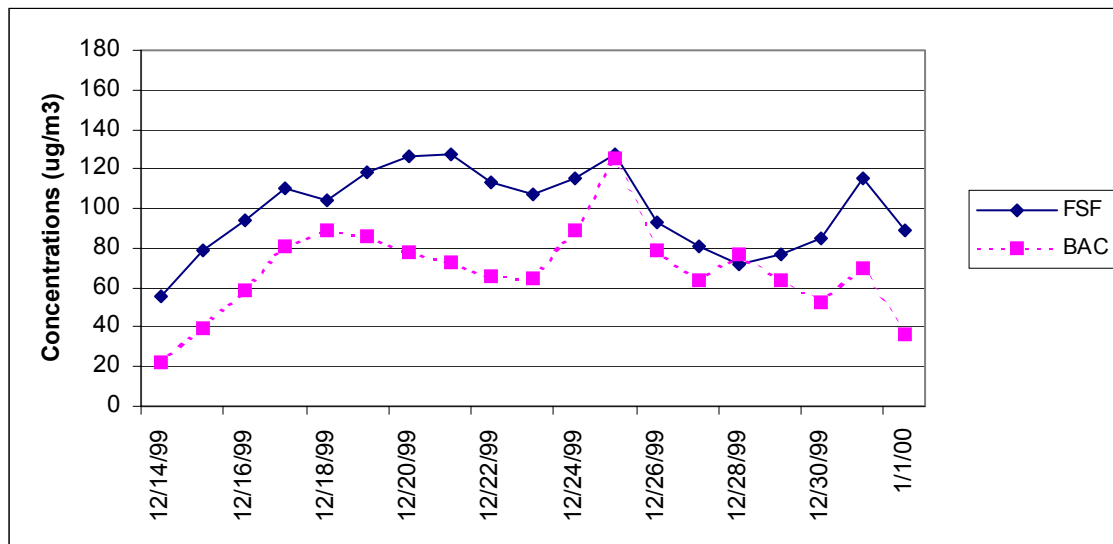
**Figure 7-5 Site-to-site variations in PM<sub>2.5</sub> concentrations among urban sites during the December 1999 episode.**



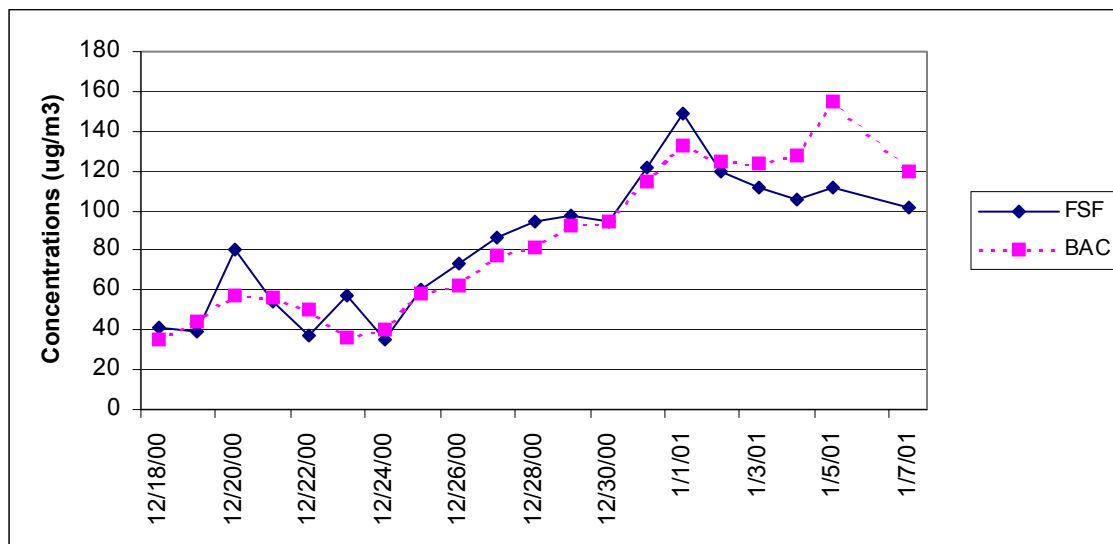
**Figure 7-6 Site-to-site variations in PM<sub>2.5</sub> concentrations among urban sites during the December 2000 episode.**



**Figure 7-7 Comparison of PM<sub>2.5</sub> concentrations at Fresno and Bakersfield during the December 1999 episode.**



**Figure 7-8 Comparison of PM<sub>2.5</sub> concentrations at Fresno and Bakersfield during the December 2000 episode.**



**Table 7-1 San Joaquin Valley urban PM<sub>2.5</sub> concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )									Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SOH	M14	MRM	CLO	FSF	VCS	COP	BAC	EDI					
12/14/99	13.2	22.1	38.5	43.8	55.4	30.3	18.9	22.5	15.7	55.4	13.2	28.9	14.2	49
12/20/99	103.2	92.5	115.9	129.5	126.6	121.0	76.8	78.1	67.1	129.5	67.1	101.2	23.5	23
12/26/99	71.3	97.7	95.0	74.1	93.2	83.5	106.6	78.6	71.7	106.6	71.3	85.7	12.8	15
1/1/00	28.0	40.6	32.8	85.0	88.8	74.2	75.3	36.7	34.5	88.8	28.0	55.1	25.0	45
Max (µg/m <sup>3</sup> )	103.2	97.7	115.9	129.5	126.6	121.0	106.6	78.6	71.7					
Min (µg/m <sup>3</sup> )	13.2	22.1	32.8	43.8	55.4	30.3	18.9	22.5	15.7					
Avg (µg/m <sup>3</sup> )	53.9	63.2	70.6	83.1	91.0	77.2	69.4	54.0	47.3					
STDEV (µg/m <sup>3</sup> )	41.1	37.6	41.3	35.5	29.1	37.3	36.6	28.8	26.8					
COV (%)	76	59	58	43	32	48	53	53	57					

**Table 7-2 San Joaquin Valley urban PM<sub>2.5</sub> concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )									Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SOH	M14	MRM	CLO	FSF	VCS	COP	BAC	EDI					
12/18/00	26.4	37.8	40.6	14.5	41.0	36.4	16.0	35.6	31.6	41.0	14.5	31.1	10.0	32
12/20/00	46.1	62.9	44.2	64.5	80.3	56.2	50.9	57.7	44.7	80.3	44.2	56.4	11.7	21
12/25/00	23.5	30.2	29.8	59.6	60.1	59.5	35.1	58.4	18.2	60.1	18.2	41.6	17.5	42
12/26/00	31.9	59.8	28.9	59.1	73.9	46.4	45.0	62.6	52.2	73.9	28.9	51.1	14.6	29
12/27/00	37.8	68.7	54.5	16.7	86.7	60.3	59.1	77.1	59.5	86.7	16.7	57.8	20.7	36
12/28/00	42.3	62.7	61.0	70.1	94.1	74.3	49.9	81.9	79.7	94.1	42.3	68.4	16.3	24
1/1/01	57.0	71.9	66.4	130.1	148.3	123.6	62.8	132.7	160.8	160.8	57.0	106.0	40.9	39
1/4/01	62.9	80.8	82.2	103.6	105.9	127.8	98.8	127.3	146.0	146.0	62.9	103.9	26.5	25
1/5/01	59.1	76.9	49.2	114.5	111.7	130.0	115.7	154.7	179.2	179.2	49.2	110.1	42.8	39
1/6/01	99.6	100.6	106.3	113.1	128.7	107.5	145.0	137.7	114.2	145.0	99.6	117.0	16.4	14
1/7/01	94.7	136.1	39.9	84.9	101.3	87.3	124.7	119.4	110.1	136.1	39.9	99.8	28.3	28
Max (µg/m <sup>3</sup> )	99.6	136.1	106.3	130.1	148.3	130.0	145.0	154.7	179.2					
Min (µg/m <sup>3</sup> )	23.5	30.2	28.9	14.5	41.0	36.4	16.0	35.6	18.2					
Avg (µg/m <sup>3</sup> )	52.8	71.7	54.8	75.5	93.8	82.7	73.0	95.0	90.6					
STDEV (µg/m <sup>3</sup> )	25.5	28.8	23.3	38.3	30.4	34.4	41.4	40.3	54.9					
COV (%)	48	40	43	51	32	42	57	42	61					

**Table 7-3 San Francisco Bay Area PM<sub>2.5</sub> concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )											Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SRF	BODG	VJO	BTI	CCD	SFA	FCW	RED	SJ4	SJT	LVR1					
12/14/99	16.7	23.0	29.7	4.6	14.8	18.5	16.8	17.7	20.6	20.6	14.6	29.7	4.6	18.0	6.2	34
12/20/99	21.5	26.1	49.2	20.1	11.2	19.6	9.0	11.2	10.9	9.5	16.9	49.2	9.0	18.7	11.6	62
12/26/99	54.9	15.2	90.5	48.4		63.4	45.2	59.7	56.9	49.6	57.0	90.5	15.2	54.1	18.6	34
1/1/00	33.5	14.0	17.0	14.3	16.0	14.5	12.2	9.5	14.1	15.8	12.7	33.5	9.5	15.8	6.2	39
Max (µg/m <sup>3</sup> )	54.9	26.1	90.5	48.4	16.0	63.4	45.2	59.7	56.9	49.6	57.0					
Min (µg/m <sup>3</sup> )	16.7	14.0	17.0	4.6	11.2	14.5	9.0	9.5	10.9	9.5	12.7					
Avg (µg/m <sup>3</sup> )	31.7	19.6	46.6	21.9	14.0	29.0	20.8	24.5	25.6	23.9	25.3					
STDEV (µg/m <sup>3</sup> )	17.0	5.9	32.1	18.8	2.5	23.0	16.6	23.7	21.2	17.7	21.2					
COV (%)	54	30	69	86	18	79	80	97	83	74	84					

**Table 7-4 San Francisco Bay Area PM<sub>2.5</sub> concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )												Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SRF	BODG	VJO	BTI	CCD	SFA	ALT1	FCW	RED	SJ4	SJT	LVR1					
12/20/00	35.8	10.4	18.4	23.1	21.9	26.4	13.5	29.6	34.3	48.0	53.0	28.8	53.0	10.4	28.6	12.8	45
12/26/00	39.5	9.7	32.7	35.6	42.4	26.2	25.1	24.4	32.8	43.3	26.1	19.7	43.3	9.7	29.8	9.9	33
12/29/00	40.1	12.0	60.1	33.5	49.9	45.4		36.3	43.0	55.3	60.8	49.7	60.8	12.0	44.2	14.0	32
1/4/01	41.9	27.4	56.0	41.0	39.4	37.8	21.4	28.8	46.1	55.4	45.8	44.2	56.0	21.4	40.4	10.5	26
1/7/01	75.9	30.2	90.1	77.9		45.5	71.7	51.0	50.9	30.5	26.1	95.4	95.4	26.1	58.7	24.8	42
Max (µg/m <sup>3</sup> )	75.9	30.2	90.1	77.9	49.9	45.5	71.7	51.0	50.9	55.4	60.8	95.4					
Min (µg/m <sup>3</sup> )	35.8	9.7	18.4	23.1	21.9	26.2	13.5	24.4	32.8	30.5	26.1	19.7					
Avg (µg/m <sup>3</sup> )	46.6	18.0	51.5	42.2	38.4	36.3	32.9	34.0	41.4	46.5	42.4	47.6					
STDEV (µg/m <sup>3</sup> )	16.5	10.0	27.5	21.0	11.9	9.6	26.3	10.4	7.7	10.3	15.8	29.3					
COV (%)	35	56	54	50	31	27	80	31	19	22	37	62					

**Table 7-5 Sacramento Valley PM<sub>2.5</sub> concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )								Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	RDG	CHM	ROS	WLN	PLE	SDP	S13	SST					
12/14/99	10	25	13	12	4.4	20	12.1	22	25.0	4.4	14.8	6.9	46
12/20/99	1	15	79	49	66.3	84	90.2	86	90.2	1.0	58.8	34.2	58
12/26/99	13	73	32	56	49.8	74	65.0	71	74.0	13.0	54.2	21.9	40
1/1/00	45	50	43	20	35.2	81	45.2	45	81.0	20.0	45.5	17.1	38
Max (µg/m <sup>3</sup> )	45.0	73.0	79.0	56.0	66.3	84.0	90.2	86.0					
Min (µg/m <sup>3</sup> )	1.0	15.0	13.0	12.0	4.4	20.0	12.1	22.0					
Avg (µg/m <sup>3</sup> )	17.3	40.8	41.8	34.3	38.9	64.8	53.1	56.0					
STDEV (µg/m <sup>3</sup> )	19.2	26.1	27.8	21.5	26.3	30.1	33.0	28.3					
COV (%)	111	64	66	63	68	47	62	51					

**Table 7-6 Sacramento Valley PM<sub>2.5</sub> concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )								Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	RDG	CSS	YAS	ROS	WLN	PLE	SDP	S13					
12/20/00	16	14	24	23	15	19.9	53	26.4	53.0	14.0	23.9	12.6	53
12/26/00	14	26	44	26	32	21.8		35.5	44.0	14.0	28.5	9.7	34
1/1/01	29	27	54	44	36	17.3	120	67.5	120.0	17.3	49.3	32.7	66
1/7/01	49	36	56	49	57	48	78	72.6	78.0	36.0	55.7	13.7	25
Max (µg/m <sup>3</sup> )	49.0	36.0	56.0	49.0	57.0	48.0	120.0	72.6					
Min (µg/m <sup>3</sup> )	14.0	14.0	24.0	23.0	15.0	17.3	53.0	26.4					
Avg (µg/m <sup>3</sup> )	27.0	25.8	44.5	35.5	35.0	26.8	83.7	50.5					
STDEV (µg/m <sup>3</sup> )	16.1	9.0	14.6	12.9	17.3	14.3	33.9	23.0					
COV (%)	60	35	33	36	49	53	40	45					

**Table 7-7 San Joaquin Valley rural/intrabasin PM<sub>2.5</sub> concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )				Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SWC	HELM	SELM	PIXL					
12/14/99	17.1	8.5	25.8		25.8	8.5	17.1	8.6	50.3
12/20/99	87.4	56.9	102.6	66.7	102.6	56.9	78.4	20.5	26.2
12/26/99	97.4	114.8	110.3	92.2	114.8	92.2	103.7	10.6	10.2
1/1/00	17.9	25.3	98.8	44.4	98.8	17.9	46.6	36.5	78.4
Max (µg/m <sup>3</sup> )	97.4	114.8	110.3	92.2					
Min (µg/m <sup>3</sup> )	17.1	8.5	25.8	44.4					
Avg (µg/m <sup>3</sup> )	55.0	51.4	84.4	67.8					
STDEV (µg/m <sup>3</sup> )	43.4	46.8	39.3	23.9					
COV (%)	79	91	47	35					

**Table 7-8 San Joaquin Valley rural/intrabasin PM<sub>2.5</sub> concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )				Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SWC	HELM	SELM	PIXL					
12/18/00	16.2	17.6	18.8	13.4	18.8	13.4	16.5	2.3	14
12/20/00	33.8	44.5	52.4	44.2	52.4	33.8	43.7	7.6	17
12/25/00	19.9	13.3	31.7	24.7	31.7	13.3	22.4	7.8	35
12/26/00	21.2	26.0	41.7	31.0	41.7	21.2	30.0	8.8	29
12/27/00	30.2	46.9	53.1	53.8	53.8	30.2	46.0	11.0	24
12/28/00	47.2	37.8	50.7	53.5	53.5	37.8	47.3	6.8	14
1/1/01	44.5	60.3	81.1	81.4	81.4	44.5	66.8	17.9	27
1/4/01	49.5	60.1	78.4	126.8	126.8	49.5	78.7	34.2	43
1/5/01	56.0	72.5	110.7	132.9	132.9	56.0	93.0	35.1	38
1/6/01	89.7	82.2	127.9	164.9	164.9	82.2	116.2	38.2	33
1/7/01	89.3	83.5	97.4	106.6	106.6	83.5	94.2	10.0	11
Max (µg/m <sup>3</sup> )	89.7	83.5	127.9	164.9					
Min (µg/m <sup>3</sup> )	16.2	13.3	18.8	13.4					
Avg (µg/m <sup>3</sup> )	45.2	49.5	67.6	75.7					
STDEV (µg/m <sup>3</sup> )	25.4	24.6	34.3	50.3					
COV (%)	56	50	51	66					

**Table 7-9 San Joaquin Valley rural/interbasin PM<sub>2.5</sub> concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )		Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SNFH	FELF					
12/14/99	25.3	3.9	25.3	3.9	14.6	15.1	103
12/20/99	43.4	27.8	43.4	27.8	35.6	11.0	31
12/26/99	21.3	26.0	26.0	21.3	23.7	3.3	14
1/1/00	70.2	5.7	70.2	5.7	38.0	45.6	120
Max (µg/m <sup>3</sup> )	70.2	27.8					
Min (µg/m <sup>3</sup> )	21.3	3.9					
Avg (µg/m <sup>3</sup> )	40.1	15.9					
STDEV (µg/m <sup>3</sup> )	22.3	12.8					
COV (%)	56	81					

**Table 7-10 San Joaquin Valley rural/interbasin PM<sub>2.5</sub> concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )		Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	FELF	SNFH					
12/18/00	18.8	8	18.8	8.0	13.4	7.6	57
12/20/00	26.7	16.5	26.7	16.5	21.6	7.2	33
12/25/00	31.8	25.5	31.8	25.5	28.7	4.5	16
12/26/00	23.9	9.5	23.9	9.5	16.7	10.2	61
12/27/00	15.2	14	15.2	14.0	14.6	0.8	6
12/28/00	38.8	26.2	38.8	26.2	32.5	8.9	27
1/1/01	69.4	29.3	69.4	29.3	49.4	28.4	57
1/4/01	67.7	25.8	67.7	25.8	46.8	29.6	63
1/5/01	82.8	35.2	82.8	35.2	59.0	33.7	57
1/6/01	11.4	20.8	20.8	11.4	16.1	6.6	41
1/7/01	20.5	10.4	20.5	10.4	15.5	7.1	46
Max (µg/m <sup>3</sup> )	82.8	35.2					
Min (µg/m <sup>3</sup> )	11.4	8.0					
Avg (µg/m <sup>3</sup> )	37.0	20.1					
STDEV (µg/m <sup>3</sup> )	24.8	9.0					
COV (%)	67	45					

**Table 7-11 Comparison of PM<sub>2.5</sub> concentrations at Fresno and Bakersfield during December episodes (Based on all matching data).**

Episode	Site ID	Concentrations (µg/m <sup>3</sup> )				Percentiles (µg/m <sup>3</sup> )			COV %	Obs Count
		Mean	SD	Minimum	Maximum	25th	50th	75th		
Dec 1999	FSF	99.45	20.95	55.41	127.82	83.17	104.45	115.22	21	19
	BAC	69.13	22.59	22.46	125.65	61.38	69.30	79.60	33	19
Dec 2000	FSF	83.59	32.59	35.68	148.33	56.88	90.39	107.31	39	20
	BAC	84.24	37.49	35.64	154.70	55.14	79.50	120.47	45	20

## 7.2 PM<sub>10</sub> Concentrations

Spatial and temporal characteristics were similar for both PM<sub>10</sub> and PM<sub>2.5</sub> size fractions. During the December 1999 episode, PM<sub>10</sub> concentrations were highest in the central San Joaquin Valley (Fresno, Visalia, and Corcoran). Site-averaged concentrations, based on four days with matching data, ranged from 106 µg/m<sup>3</sup> to 116 µg/m<sup>3</sup> in the central Valley and from 61 µg/m<sup>3</sup> to 81 µg/m<sup>3</sup> in the northern and southern Valley (Table 7-12). During the December 2000 episode, highest concentrations were found in the central and southern San Joaquin Valley (Table 7-13). The Bakersfield-Golden monitoring site, with a four-day average concentration of 151 µg/m<sup>3</sup> and a peak of 205 µg/m<sup>3</sup>, was the highest PM<sub>10</sub> site. Concentrations at Fresno-Drummond and Bakersfield-California were only slightly lower with average concentrations of 130 µg/m<sup>3</sup> and 136 µg/m<sup>3</sup>, respectively, and a peak of 186 µg/m<sup>3</sup> at both sites.

The average concentration for the seven sites was 90 µg/m<sup>3</sup> during the December 1999 episode, but 122 µg/m<sup>3</sup> in December 2000. Peak concentrations were also significantly higher. Based on the complete data set (rather than the matching data listed in Table 7-12 and Table 7-13) PM<sub>10</sub> concentrations peaked at 174 µg/m<sup>3</sup> during the December 1999 episode and at 208 µg/m<sup>3</sup> during the December 2000 episode.

The day-to-day variations in concentrations were similar for both PM<sub>2.5</sub> and PM<sub>10</sub> fractions. The most uniform concentrations were also achieved on the same day for both size fractions, December 26, 1999 during the December 1999 episode and January 7, 2001, during the December 2000 episode.

PM<sub>10</sub> concentrations in the San Francisco Bay Area and Sacramento Valley Air Basins remained far below the 24-hr PM<sub>10</sub> NAAQS during each episode. In the San Francisco Bay Area, peak concentrations reached 84 µg/m<sup>3</sup> during the December 1999 episode (Table 7-14) and 109 µg/m<sup>3</sup> during December 2000 (Table 7-15). Concentrations were fairly uniform with the average ranging from 28 µg/m<sup>3</sup> to 48 µg/m<sup>3</sup> during the December 1999 episode and from 48 µg/m<sup>3</sup> to 68 µg/m<sup>3</sup> during the December 2000 episode. In the Sacramento Valley, the peak concentrations were 109 µg/m<sup>3</sup> during the December 1999 episode (Table 7-16) and 105 µg/m<sup>3</sup> during December 2000 (Table 7-17). Concentrations were less uniform compared to the Bay Area. The site-averaged concentrations ranged

from 23  $\mu\text{g}/\text{m}^3$  to 68  $\mu\text{g}/\text{m}^3$  during the December 1999 episode and from 33  $\mu\text{g}/\text{m}^3$  to 73  $\mu\text{g}/\text{m}^3$  during the December 2000 episode.

**Table 7-12 San Joaquin Valley PM<sub>10</sub> concentrations during the December 1999 episode.**

Date	Concentrations ( $\mu\text{g}/\text{m}^3$ )							Max ( $\mu\text{g}/\text{m}^3$ )	Min ( $\mu\text{g}/\text{m}^3$ )	Avg ( $\mu\text{g}/\text{m}^3$ )	STDEV ( $\mu\text{g}/\text{m}^3$ )	COV (%)
	M14	FSF	VCS	COP	OLD	BGS	BAC					
12/14/99	39	71	53	49	37	41	41	71	37	47	12	25
12/20/99	124	154	152	115	91	109	97	154	91	120	25	21
12/26/99	109	124	102	145	81	120	109	145	81	113	20	18
1/1/00	50	113	141	113	33	48	59	141	33	80	42	52
Max ( $\mu\text{g}/\text{m}^3$ )	124	154	152	145	91	120	109					
Min ( $\mu\text{g}/\text{m}^3$ )	39	71	53	49	33	41	41					
Avg ( $\mu\text{g}/\text{m}^3$ )	81	116	112	106	61	80	77					
STDEV ( $\mu\text{g}/\text{m}^3$ )	42	34	45	40	30	41	32					
COV (%)	52	30	40	38	49	51	42					

**Table 7-13 San Joaquin Valley PM<sub>10</sub> concentrations during the December 2000 episode.**

Date	Concentrations ( $\mu\text{g}/\text{m}^3$ )							Max ( $\mu\text{g}/\text{m}^3$ )	Min ( $\mu\text{g}/\text{m}^3$ )	Avg ( $\mu\text{g}/\text{m}^3$ )	STDEV ( $\mu\text{g}/\text{m}^3$ )	COV (%)
	M14	FSD	VCS	COP	OLD	BGS	BAC					
12/23/00	44	85	81	70	48	72	57	85	44	65	16	24
12/29/00	99	120	104	111	133	153	140	153	99	123	20	16
1/1/01	88	186	143	87	158	205	186	205	87	150	48	32
1/7/01	158	131	122	165	139	174	159	174	122	150	19	13
Max ( $\mu\text{g}/\text{m}^3$ )	158	186	143	165	158	205	186					
Min ( $\mu\text{g}/\text{m}^3$ )	44	85	81	70	48	72	57					
Avg ( $\mu\text{g}/\text{m}^3$ )	97	130	113	108	120	151	136					
STDEV ( $\mu\text{g}/\text{m}^3$ )	47	42	26	42	49	57	56					
COV (%)	48	32	23	38	41	37	41					

**Table 7-14 San Francisco Bay Area PM<sub>10</sub> concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )												Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SRF	NAP	VJO	PBG	BTIR	SRL	CCD	SFA	LVF	FCW	RED	SJ4					
12/14/99	23	23.4	31	17.6	12.7	23.7	20.3	38.3	29	26.7	32	35.2	38	13	26	7	28
12/20/99	28	33.4	46	35.1	56.5	34.5	17.5	41.7	34	15.1	27.9	26	57	15	33	12	35
12/26/99	54	52.5	84	70	60.5	64.4	61.7	69.4	65	50.2	58.4	63.7	84	50	63	9	14
1/1/00	35	25.6	17	27.2	22	17.5	20.1	20.6	17	20.1	14.9	22.3	35	15	22	6	26
Max (µg/m <sup>3</sup> )	54	53	84	70	61	64	62	69	65	50	58	64					
Min (µg/m <sup>3</sup> )	23	23	17	18	13	18	18	21	17	15	15	22					
Avg (µg/m <sup>3</sup> )	35	34	45	37	38	35	30	43	36	28	33	37					
STDEV (µg/m <sup>3</sup> )	14	13	29	23	24	21	21	20	20	16	18	19					
COV (%)	39	39	64	61	64	59	71	47	56	55	55	51					

**Table 7-15 San Francisco Bay Area PM<sub>10</sub> concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )												Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SRF	NAP	VJO	PBG	BTIR	SRL	CCD	SFA	LVR1	FCW	RED	SJ4					
12/20/00	46	43.1	17	30.3	25.7	33.7	30	63.2	43	48.1	48.4	76.1	76	17	42	16	39
12/26/00		40.8	28	41.3	38.5	36.3	39.4	43.1	41	32.1	40	64	64	28	40	9	22
1/1/01	64	55.3	59	70.3	57.3	50.2	82.1	54.8	77	54.5	59.2	76.7	82	50	63	11	17
1/7/01	74	90.9	86	97.7	86.8	78.8	106	64.6	109	57.6	52.5	42	109	42	79	21	27
Max (µg/m <sup>3</sup> )	74	91	86	98	87	79	106	65	109	58	59	77					
Min (µg/m <sup>3</sup> )	46	41	17	30	26	34	30	43	41	32	40	42					
Avg (µg/m <sup>3</sup> )	61	58	48	60	52	50	64	56	68	48	50	65					
STDEV (µg/m <sup>3</sup> )	14	23	31	30	27	21	36	10	32	11	8	16					
COV (%)	23	40	66	51	51	42	56	18	48	24	16	25					

**Table 7-16 Sacramento Valley PM<sub>10</sub> concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )											Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	ANDE	CHM	RDG	REDB	ROC	ROS	S13	SDP	SNH	VAC	WSA					
12/14/99	34	32	15	22	20	23	26	25	32	20	35	35	15	26	7	26
12/20/99	19	26	7	8	70	76	99	75	55	23	109	109	7	52	37	71
12/26/99	39	75	20	32	28	36	66	68	42	59	78	78	20	49	20	41
1/1/00	49	57	49	41	32	50	57	58	82	36	49	82	32	51	13	26
Max (µg/m <sup>3</sup> )	49	75	49	41	70	76	99	75	82	59	109					
Min (µg/m <sup>3</sup> )	19	26	7	8	20	23	26	25	32	20	35					
Avg (µg/m <sup>3</sup> )	35	48	23	26	38	46	62	57	53	35	68					
STDEV (µg/m <sup>3</sup> )	13	23	18	14	22	23	30	22	22	18	33					
COV (%)	35	48	80	55	59	49	48	39	41	51	48					

**Table 7-17 Sacramento Valley PM<sub>10</sub> concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )											Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	ANDE	CHM	RDG	REDB	ROC	ROS	S13	SDP	SNH	VAC	WSA					
12/20/00	39	58	31	34	21	34	48	43	38	39	52	58	21	40	10	26
12/26/00	31	67	23	32	23	38		55	45	44	66	67	23	42	16	38
1/1/01	38	105	34	44	31	49	83	60	44	70	77	105	31	58	23	41
1/7/01	66	101	56	44	57	58	89	23	30	77	95	101	23	63	26	40
Max (µg/m <sup>3</sup> )	66	105	56	44	57	58	89	60	45	77	95					
Min (µg/m <sup>3</sup> )	31	58	23	32	21	34	48	23	30	39	52					
Avg (µg/m <sup>3</sup> )	44	83	36	39	33	45	73	45	39	58	73					
STDEV (µg/m <sup>3</sup> )	15	24	14	6	17	11	22	16	7	19	18					
COV (%)	35	29	39	17	50	24	30	36	18	33	25					

### 7.3 PM<sub>2.5</sub> Chemical Species

During each episode the PM<sub>10</sub> mass was dominated by PM<sub>2.5</sub>. The Valley-wide average ratio of PM<sub>2.5</sub> to PM<sub>10</sub> for both December 1999 and December 2000 episodes was approximately 70%. The coarse fraction of PM<sub>10</sub> (the difference between PM<sub>10</sub> and PM<sub>2.5</sub>) was primarily composed of geological material. Since the PM<sub>10</sub> chemical composition data are limited, this section will focus on PM<sub>2.5</sub> chemical species. The two most abundant chemical components are ammonium nitrate and carbonaceous aerosols. Together they comprise over 80% of the PM<sub>2.5</sub> mass. Each component has a unique spatial and temporal pattern. Table 7-18 through Table 7-35 summarize the data for each site during the December 1999 and December 2000 episode.

#### 7.3.1 Ammonium Nitrate

Ammonium nitrate exhibited a very distinct buildup pattern. At the beginning of the episode, concentrations were low but increased steadily until they reached a peak. Concentrations remained high until a low pressure system moved into the area, broke down the atmosphere and scavenged the particles with rain. The rate of buildup depended on the meteorology of the episode as well as individual characteristics. For example, during the December 1999 episode, concentrations climbed so rapidly that on December 20, only six days into the episode, the average concentration for the eight urban sites was 62 µg/m<sup>3</sup> with only 16% variation in the data (Table 7-18). The buildup rate was significantly slower during the December 2000 episode. The highest and most uniform concentrations were seen on Day 20 (January 6, 2001) when the average for the eight urban sites was 61 µg/m<sup>3</sup> with a 26% variation (Table 7-23). Concentrations at rural sites increased at a pace slower than urban but reached higher levels. During the December 1999 episode, rural sites achieved their peak six days later than urban (Table 7-24). The average rural concentrations not only slightly exceeded urban concentrations (65 µg/m<sup>3</sup> versus 62 µg/m<sup>3</sup>), but were also much more uniform (4% variation versus 16%). Similarly, during the December 2000 episode, high ammonium nitrate concentrations were first recorded at the urban sites but were exceeded on the last few days at the rural/intrabasin sites. Variations were still higher among the rural sites than urban, due in part to the fact that the Southwest Chowchilla site never reached concentrations as high as other sites, unlike its pattern in 1999.

Ammonium nitrate concentrations showed significant variation during a PM episode. This variability reflected the very nature of an episode as it encompassed the entire period from low beginning concentrations through the buildup to peak concentrations, and finally dissolution. Geographic location determined variation more than site character (urban versus rural). During the December 1999 episode, concentrations were less variable in the central Valley (60-70%) than in the northern and southern Valley (about 100%). During the December 2000 episode, most sites had a 60-80% variation in ammonium nitrate concentrations. The lowest variation (35%) was found at the Fresno-1<sup>st</sup> Street site, but these data were incomplete.

During the December 2000 episode, concentrations of ammonium nitrate in the San Francisco Bay Area and Sacramento Valley Air Basins followed their own temporal pattern until the last few days of the episode. Between January 5 and 7, ammonium nitrate concentrations at some Bay Area sites (Livermore and Bethel Island) increased 60% each day while concentrations at other Bay Area sites, including San Jose-4<sup>th</sup> and San Francisco-Arkansas, remained unchanged. Ammonium nitrate concentrations also increased at a Sacramento Valley monitoring site, Sacramento-13<sup>th</sup> Street, but not as significantly. The December 1999 ammonium nitrate data were incomplete for several monitoring sites in the Bay Area. However, the available data indicates that Bethel Island and San Francisco-Arkansas monitoring sites both experienced an increase in ammonium nitrate concentration on December 26, 1999, the same day when rural sites in the San Joaquin Valley achieved their peak concentrations.

### **7.3.2 Carbonaceous aerosols**

Carbonaceous aerosols were the second largest component of the PM<sub>2.5</sub> mass. However, its spatial and temporal patterns were very different from ammonium nitrate. For instance, the buildup of carbonaceous aerosols was much less pronounced. As shown in Figure 7-10, during the December 2000 episode average concentrations of ammonium nitrate across the eight urban sites increased from 10 to 61  $\mu\text{g}/\text{m}^3$  but carbonaceous aerosols concentrations only increased from 14 to 36  $\mu\text{g}/\text{m}^3$ . Since carbonaceous aerosols concentrations did not change as much as nitrate from one day to another, the coefficient of variation was about 2 to 3 times smaller. For example, an average urban site experienced 81% variation in ammonium nitrate concentrations but only 28% variation in carbonaceous aerosols during the December 1999 episode. The difference was smaller, but still very significant, during the December 2000 episode, with 62% variation in ammonium nitrate and 29% in carbonaceous aerosols. However, while carbonaceous aerosols concentrations were more uniform on a day-to-day basis, they were much more variable spatially. Spatial variations were the same from one episode to another with concentrations always following this order (listed from the highest concentration to the lowest):

- urban sites,
- rural/intrabasin sites, and
- rural/interbasin.

Carbonaceous aerosols concentrations were always higher at Fresno than at the other urban sites. The difference was not very significant during the December 1999 episode because peak carbonaceous aerosols concentrations were only moderately high ranging from 25  $\mu\text{g}/\text{m}^3$  at Visalia to 38  $\mu\text{g}/\text{m}^3$  at Fresno. However, during the December 2000 episode peak carbonaceous aerosols concentrations ranged from 23  $\mu\text{g}/\text{m}^3$  at Corcoran to 92  $\mu\text{g}/\text{m}^3$  at Fresno. Furthermore, while the episode-averaged carbonaceous aerosols concentration reached 59  $\mu\text{g}/\text{m}^3$  at Fresno, concentrations at the other seven urban sites ranged from 16  $\mu\text{g}/\text{m}^3$  at Corcoran to 33  $\mu\text{g}/\text{m}^3$  at Bakersfield. The average rural/intrabasin concentrations ranged from 7  $\mu\text{g}/\text{m}^3$  at Southwest Chowchilla to 21  $\mu\text{g}/\text{m}^3$  at Selma. Selma always had the highest carbonaceous aerosols concentrations of all rural sites due to its

proximity to Fresno. Rural/interbasin sites were less variable, with averages ranging from 7  $\mu\text{g}/\text{m}^3$  at Foothills above Fellows to 9.5  $\mu\text{g}/\text{m}^3$  at Sierra Nevada Foothills.

In the San Joaquin Valley and Sacramento Valley air basins carbonaceous aerosols concentrations exhibited their own temporal pattern, different from ammonium nitrate. In the San Francisco Bay Area both components tracked each other better than in the San Joaquin Valley. This is especially evident on the last few days of the December 2000 episode, when both ammonium nitrate and carbonaceous aerosols increased in concentration at Livermore and Bethel Island, unlike similar sites in the San Joaquin Valley.

**Table 7-18 San Joaquin Valley urban  $\text{PM}_{2.5}$  ammonium nitrate concentrations during the December 1999 episode.**

Date	Concentrations ( $\mu\text{g}/\text{m}^3$ )								Max ( $\mu\text{g}/\text{m}^3$ )	Min ( $\mu\text{g}/\text{m}^3$ )	Avg ( $\mu\text{g}/\text{m}^3$ )	STDEV ( $\mu\text{g}/\text{m}^3$ )	COV (%)
	SOH	M14	MRM	CLO	FSF	VCS	COP	BAC					
12/14/99	3.3	3.6	9.6	10.8	12.2	5.9	5.6	6.4	12.2	3.3	7.2	3.3	46.3
12/20/99	67.5	61.0	61.0	73.9	72.4	50.8	48.5		73.9	48.5	62.2	9.9	16.0
12/26/99	40.3		47.2	41.0	43.5	42.2	73.3	45.8	73.3	40.3	47.6	11.6	24.4
1/1/00	9.0	8.9	14.0	41.6	38.8	47.8	42.5	12.6	47.8	8.9	26.9	17.1	63.5
Max ( $\mu\text{g}/\text{m}^3$ )	67.5	61.0	61.0	73.9	72.4	50.8	73.3	45.8					
Min ( $\mu\text{g}/\text{m}^3$ )	3.3	3.6	9.6	10.8	12.2	5.9	5.6	6.4					
Avg ( $\mu\text{g}/\text{m}^3$ )	30.0	24.5	33.0	41.8	41.7	36.7	42.5	21.6					
STDEV ( $\mu\text{g}/\text{m}^3$ )	29.8	31.7	25.1	25.8	24.7	20.8	28.0	21.2					
COV (%)	99.2	129.5	76.2	61.6	59.1	56.8	65.9	98.1					

**Table 7-19 San Joaquin Valley urban  $\text{PM}_{2.5}$  carbonaceous aerosols concentrations during the December 1999 episode.**

Date	Concentrations ( $\mu\text{g}/\text{m}^3$ )								Max ( $\mu\text{g}/\text{m}^3$ )	Min ( $\mu\text{g}/\text{m}^3$ )	Avg ( $\mu\text{g}/\text{m}^3$ )	STDEV ( $\mu\text{g}/\text{m}^3$ )	COV (%)
	SOH	M14	MRM	CLO	FSF	VCS	COP	BAC					
12/14/99	16.9	19.3	27.0	25.8	38.1	15.5	11.3	16.1	38.1	11.3	21.2	8.6	40.4
12/20/99	23.1	25.4	31.8	37.6		21.7	20.7		37.6	20.7	26.7	6.7	24.9
12/26/99	20.5		33.8	31.1	37.9	23.9	19.8	26.5	37.9	19.8	27.6	6.9	24.8
1/1/00	10.2	14.6	13.3	23.2	28.2	24.8	32.2	15.8	32.2	10.2	20.3	7.9	38.9
Max ( $\mu\text{g}/\text{m}^3$ )	23.1	25.4	33.8	37.6	38.1	24.8	32.2	26.5					
Min ( $\mu\text{g}/\text{m}^3$ )	10.2	14.6	13.3	23.2	28.2	15.5	11.3	15.8					
Avg ( $\mu\text{g}/\text{m}^3$ )	17.7	19.8	26.5	29.4	34.7	21.5	21.0	19.5					
STDEV ( $\mu\text{g}/\text{m}^3$ )	5.6	5.4	9.2	6.4	5.6	4.2	8.6	6.1					
COV (%)	31.8	27.2	34.8	21.7	16.2	19.4	40.8	31.3					

**Table 7-20 San Joaquin Valley urban PM<sub>2.5</sub> ammonium sulfate concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )								Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SOH	M14	MRM	CLO	FSF	VCS	COP	BAC					
12/14/99	0.9	1.0	1.4	1.3	1.3	1.3	0.9	0.8	1.4	0.8	1.1	0.2	21.1
12/20/99	4.7	5.0	4.3	4.5	5.0	3.2	3.1		5.0	3.1	4.3	0.8	18.5
12/26/99	2.5		2.9	2.1	2.7	2.1	4.9	2.9	4.9	2.1	2.9	1.0	32.9
1/1/00	3.4	5.1	3.9	6.5	7.2	6.7	5.7	5.3	7.2	3.4	5.5	1.3	24.2
Max (µg/m <sup>3</sup> )	4.7	5.1	4.3	6.5	7.2	6.7	5.7	5.3					
Min (µg/m <sup>3</sup> )	0.9	1.0	1.4	1.3	1.3	1.3	0.9	0.8					
Avg (µg/m <sup>3</sup> )	2.9	3.7	3.1	3.6	4.1	3.3	3.7	3.0					
STDEV (µg/m <sup>3</sup> )	1.6	2.3	1.3	2.3	2.6	2.3	2.1	2.3					
COV (%)	55.5	62.8	41.1	65.5	63.9	69.9	57.7	75.2					

**Table 7-21 San Joaquin Valley urban PM<sub>2.5</sub> ammonium nitrate concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )								Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SOH	M14	MRM	CLO	FSF	VCS	COP	BAC					
12/18/00	10.1	12.7	11.4	9.5		2.1	6.2	17.9	17.9	2.1	10.0	5.0	49.6
12/20/00	14.1	10.8	21.4	23.9		22.3	22.6	25.5	25.5	10.8	20.1	5.5	27.1
12/25/00	5.1	5.5	9.8	18.8		17.9	13.5		18.8	5.1	11.8	6.0	50.8
12/26/00	9.2	8.6	14.6	17.9	18.7	16.8	7.4	25.3	25.3	7.4	14.8	6.1	41.3
12/27/00	14.3	18.0	15.6	17.1	18.7	26.0		33.3	33.3	14.3	20.4	6.8	33.3
12/28/00	14.5	21.5	30.0	23.0	24.4	33.5	26.3	45.7	45.7	14.5	27.4	9.3	34.1
1/1/01	20.6	29.6	36.9	64.7		54.8	27.8	78.0	78.0	20.6	44.6	21.5	48.1
1/4/01	24.7	34.5	33.2	48.9	39.5	53.2	57.3	76.6	76.6	24.7	46.0	16.5	36.0
1/5/01	22.3	27.0	29.2	61.9	40.6	73.9	75.9		75.9	22.3	47.3	22.9	48.5
1/6/01	44.9	57.2	56.4	61.6	45.1	71.9	89.9		89.9	44.9	61.0	15.8	25.9
1/7/01	61.8	63.1	46.8	37.1	41.4	40.9	73.0		73.0	37.1	52.0	13.8	26.6
Max (µg/m <sup>3</sup> )	61.8	63.1	56.4	64.7	45.1	73.9	89.9	78.0					
Min (µg/m <sup>3</sup> )	5.1	5.5	9.8	9.5	18.7	2.1	6.2	17.9					
Avg (µg/m <sup>3</sup> )	22.0	26.2	27.8	34.9	32.6	37.6	40.0	43.2					
STDEV (µg/m <sup>3</sup> )	17.0	19.1	15.0	20.7	11.5	23.5	31.1	24.9					
COV (%)	77.4	72.8	54.1	59.4	35.4	62.5	77.8	57.6					

**Table 7-22 San Joaquin Valley urban PM<sub>2.5</sub> carbonaceous aerosols concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )								Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SOH	M14	MRM	CLO	FSF	VCS	COP	BAC					
12/18/00	11.3	15.5	25.2	15.9		5.6	7.5	17.3	25.2	5.6	14.0	6.6	47.2
12/20/00	21.6	28.6	26.0	22.7	63.2	20.2	19.5	25.2	63.2	19.5	28.4	14.4	50.7
12/25/00	17.7	25.7	19.8	34.7		27.8	17.5		34.7	17.5	23.9	6.8	28.5
12/26/00	14.5	26.1	15.1	25.3	46.0	18.1	3.6	31.4	46.0	3.6	22.5	12.8	56.8
12/27/00	23.7	43.2	27.3	27.4	57.2	26.3		39.6	57.2	23.7	35.0	12.3	35.0
12/28/00	17.0	35.3	35.3	18.7	56.4	20.1	14.3	35.4	56.4	14.3	29.1	14.2	48.9
1/1/01	14.2	26.2	27.3	36.9	92.3	32.7	13.2	42.0	92.3	13.2	35.6	25.0	70.3
1/4/01	26.9	38.0	36.8	32.2	49.8	33.6	20.3	40.5	49.8	20.3	34.8	8.9	25.6
1/5/01	25.8	34.2	21.7	40.0	51.8	29.2	20.2		51.8	20.2	31.8	11.2	35.2
1/6/01	19.6	27.9	30.7	37.9	61.8	27.2	22.6		61.8	19.6	32.5	14.2	43.6
1/7/01	30.6	31.5	25.0	34.3	56.3	24.7	22.9		56.3	22.9	32.2	11.4	35.5
Max (µg/m <sup>3</sup> )	30.6	43.2	36.8	40.0	92.3	33.6	22.9	42.0					
Min (µg/m <sup>3</sup> )	11.3	15.5	15.1	15.9	46.0	5.6	3.6	17.3					
Avg (µg/m <sup>3</sup> )	20.3	30.2	26.4	29.6	59.4	24.1	16.2	33.1					
STDEV (µg/m <sup>3</sup> )	6.0	7.4	6.4	8.1	13.5	7.9	6.5	9.1					
COV (%)	29.8	24.5	24.1	27.4	22.7	32.8	40.0	27.5					

**Table 7-23 San Joaquin Valley urban PM<sub>2.5</sub> ammonium sulfate concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )								Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SOH	M14	MRM	CLO	FSF	VCS	COP	BAC					
12/18/00	1.6	3.8	2.2	1.6		0.4	1.3	2.6	3.8	0.4	1.9	1.1	56.3
12/20/00	2.1	2.0	2.4	1.7		2.0	2.7	2.9	2.9	1.7	2.3	0.4	18.0
12/25/00	0.8	1.2	1.5	2.7		2.8	2.3		2.8	0.8	1.9	0.8	44.4
12/26/00	1.3	1.4	1.7	2.3	2.3	2.1	1.0	3.9	3.9	1.0	2.0	0.9	44.8
12/27/00	2.4	2.6	1.8	1.8	1.9	2.7		4.2	4.2	1.8	2.5	0.8	33.6
12/28/00	1.9	2.8	2.3	1.6	2.0	2.9	2.7	4.0	4.0	1.6	2.5	0.7	29.5
1/1/01	2.7	2.9	2.8	3.9		3.9	2.5	7.8	7.8	2.5	3.8	1.9	49.7
1/4/01	2.4	3.0	2.9	3.5	3.1	4.7	4.1	6.0	6.0	2.4	3.7	1.2	31.0
1/5/01	2.4	2.7	2.0	3.6	2.9	4.4	5.1		5.1	2.0	3.3	1.1	34.3
1/6/01	3.2	4.6	3.7	4.0	3.1	4.3	6.0		6.0	3.1	4.1	1.0	23.8
1/7/01	4.4	5.1	3.3	2.3	2.7	2.6	4.9		5.1	2.3	3.6	1.2	32.4
Max (µg/m <sup>3</sup> )	4.4	5.1	3.7	4.0	3.1	4.7	6.0	7.8					
Min (µg/m <sup>3</sup> )	0.8	1.2	1.5	1.6	1.9	0.4	1.0	2.6					
Avg (µg/m <sup>3</sup> )	2.3	2.9	2.4	2.7	2.6	3.0	3.3	4.5					
STDEV (µg/m <sup>3</sup> )	1.0	1.2	0.7	0.9	0.5	1.3	1.7	1.9					
COV (%)	41.8	42.1	29.1	35.7	19.5	42.4	51.5	41.4					

**Table 7-24 San Joaquin Valley rural/intrabasin PM<sub>2.5</sub> ammonium nitrate concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )				Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SWC	HELM	SELM	PIXL					
12/14/99	6.9	3.9	9.0		9.0	3.9	6.6	2.6	39.1
12/20/99	33.2	35.5	57.3	43.1	57.3	33.2	42.3	10.9	25.7
12/26/99	63.4		62.9	68.0	68.0	5.1	64.8	2.8	4.4
1/1/00	5.1	13.0	41.8	28.3	41.8	3.9	22.1	16.3	74.1
Max (µg/m <sup>3</sup> )	63.4	35.5	62.9	68.0					
Min (µg/m <sup>3</sup> )	5.1	3.9	9.0	28.3					
Avg (µg/m <sup>3</sup> )	27.2	17.5	42.8	46.5					
STDEV (µg/m <sup>3</sup> )	27.4	16.3	24.2	20.1					
COV (%)	100.7	93.4	56.6	43.1					

**Table 7-25 San Joaquin Valley rural/intrabasin PM<sub>2.5</sub> carbonaceous aerosols concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )				Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SWC	HELM	SELM	PIXL					
12/14/99	7.3	3.5	13.4		13.4	3.5	8.1	5.0	61.9
12/20/99	11.9	14.6	27.5	13.1	27.5	11.9	16.8	7.3	43.2
12/26/99	21.1		31.6	17.8	31.6	4.3	23.5	7.2	30.8
1/1/00	4.3	9.3	25.1	12.1	25.1	3.0	12.7	8.9	70.0
Max (µg/m <sup>3</sup> )	21.1	14.6	31.6	17.8					
Min (µg/m <sup>3</sup> )	4.3	3.5	13.4	12.1					
Avg (µg/m <sup>3</sup> )	11.1	9.1	24.4	14.3					
STDEV (µg/m <sup>3</sup> )	7.3	5.5	7.8	3.0					
COV (%)	65.9	60.7	32.0	21.2					

**Table 7-26 San Joaquin Valley rural/intrabasin PM<sub>2.5</sub> ammonium sulfate concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )				Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SWC	HELM	SELM	PIXL					
12/14/99	0.9	0.8	1.4		1.4	0.8	1.0	0.3	33.2
12/20/99	2.2	2.2	3.7	2.7	3.7	2.2	2.7	0.7	26.9
12/26/99	3.6		3.7	3.8	3.8	3.6	3.7	0.1	2.9
1/1/00	1.4	2.6	6.3	3.1	6.3	1.4	3.3	2.1	62.1
Max (µg/m <sup>3</sup> )	3.6	2.6	6.3	3.8					
Min (µg/m <sup>3</sup> )	0.9	0.8	1.4	2.7					
Avg (µg/m <sup>3</sup> )	2.0	1.9	3.8	3.2					
STDEV (µg/m <sup>3</sup> )	1.2	1.0	2.0	0.6					
COV (%)	59.8	51.8	52.5	17.6					

**Table 7-27 San Joaquin Valley rural/intrabasin PM<sub>2.5</sub> ammonium nitrate concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )				Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SWC	HELM	SELM	PIXL					
12/18/00	8.6	8.1	8.5	7.5	8.6	7.5	8.2	0.5	6.2
12/20/00	22.6	10.4	27.7	21.1	27.7	10.4	20.5	7.3	35.6
12/25/00		5.1	12.7	11.8	12.7	5.1	9.9	4.2	42.1
12/26/00	11.5	14.2	15.6	9.8	15.6	9.8	12.8	2.6	20.6
12/27/00	18.5	19.3	21.1	36.2	36.2	18.5	23.8	8.3	35.0
12/28/00	9.5	24.1	26.3	37.2	37.2	9.5	24.3	11.4	47.0
1/1/01	27.2		43.5	51.1	51.1	27.2	40.6	12.2	30.0
1/4/01	16.8	38.3	44.8	68.9	68.9	16.8	42.2	21.4	50.8
1/5/01	37.7		68.5	90.9	90.9	37.7	65.7	26.7	40.6
1/6/01	25.4	61.1	76.7	100.3	100.3	25.4	65.9	31.4	47.7
1/7/01	25.5	51.3	70.6	71.9	71.9	25.5	54.8	21.7	39.6
Max (µg/m <sup>3</sup> )	37.7	61.1	76.7	100.3					
Min (µg/m <sup>3</sup> )	8.6	5.1	8.5	7.5					
Avg (µg/m <sup>3</sup> )	20.3	25.8	37.8	46.1					
STDEV (µg/m <sup>3</sup> )	9.2	20.0	24.7	33.1					
COV (%)	45.2	77.7	65.3	71.8					

**Table 7-28 San Joaquin Valley rural/intrabasin PM<sub>2.5</sub> carbonaceous aerosols concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )				Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SWC	HELM	SELM	PIXL					
12/18/00	4.0	3.0	9.6	4.5	9.6	2.0	5.3	2.9	56.0
12/20/00	5.7	2.0	18.4	10.0	18.4	2.0	9.1	7.1	78.0
12/25/00		6.5	13.7	9.8	13.7	2.7	10.0	3.6	36.3
12/26/00	3.9	7.3	18.8	2.7	18.8	2.7	8.2	7.3	89.7
12/27/00	6.7	6.2	22.8	10.8	22.8	3.1	11.6	7.7	66.2
12/28/00	3.1	9.4	17.6	9.9	17.6	3.1	10.0	5.9	59.1
1/1/01	9.9		30.6	12.6	30.6	5.4	17.7	11.3	63.6
1/4/01	5.4	11.6	19.7	14.3	19.7	5.4	12.8	6.0	46.7
1/5/01	12.2		30.2	18.0	30.2	6.7	20.1	9.2	45.5
1/6/01	6.7	18.9	19.7	16.3	19.7	6.7	15.4	6.0	38.8
1/7/01	9.6	10.2	27.7	16.4	27.7	2.0	16.0	8.4	52.5
Max (µg/m <sup>3</sup> )	12.2	18.9	30.6	18.0					
Min (µg/m <sup>3</sup> )	3.1	2.0	9.6	2.7					
Avg (µg/m <sup>3</sup> )	6.7	8.3	20.8	11.4					
STDEV (µg/m <sup>3</sup> )	3.0	5.1	6.6	4.8					
COV (%)	44.2	60.7	31.7	42.3					

**Table 7-29 San Joaquin Valley rural/intrabasin PM<sub>2.5</sub> ammonium sulfate concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )				Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SWC	HELM	SELM	PIXL					
12/18/00	1.3	1.1	1.4	1.5	1.5	1.0	1.3	0.1	10.3
12/20/00	1.9	1.0	2.6	2.1	2.6	0.7	1.9	0.7	34.3
12/25/00		0.7	1.8	1.7	1.8	0.7	1.4	0.6	43.8
12/26/00	1.4	1.5	1.9	1.2	1.9	1.2	1.5	0.3	21.5
12/27/00	1.6	1.9	2.6	3.3	3.3	1.0	2.4	0.8	33.0
12/28/00	1.0	2.0	2.2	5.8	5.8	1.0	2.8	2.1	75.8
1/1/01	1.6		3.4	4.1	4.1	1.2	3.0	1.3	42.5
1/4/01	1.2	2.7	3.2	4.4	4.4	1.2	2.9	1.3	46.1
1/5/01	2.3		4.9	5.4	5.4	1.8	4.2	1.7	40.1
1/6/01	1.8	4.0	4.9	5.7	5.7	1.7	4.1	1.7	41.3
1/7/01	1.7	3.2	4.4	4.3	4.4	0.4	3.4	1.2	36.6
Max (µg/m <sup>3</sup> )	2.3	4.0	4.9	5.8					
Min (µg/m <sup>3</sup> )	1.0	0.7	1.4	1.2					
Avg (µg/m <sup>3</sup> )	1.6	2.0	3.0	3.6					
STDEV (µg/m <sup>3</sup> )	0.4	1.1	1.2	1.7					
COV (%)	24.2	53.8	40.7	48.6					

**Table 7-30 San Joaquin Valley rural/interbasin PM<sub>2.5</sub> ammonium nitrate concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )			Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SNFH	FEL	FELF					
12/14/99	8.9	2.8		8.9	2.8	5.8	4.3	74.1
12/20/99	20.1	18.9	18.2	20.1	18.2	19.1	1.0	5.0
12/26/99	5.1	22.4	19.9	22.4	5.1	15.8	9.3	59.0
1/1/00	39.8		1.5	39.8	1.5	20.6	27.1	131.1
Max (µg/m <sup>3</sup> )	39.8	22.4	19.9					
Min (µg/m <sup>3</sup> )	5.1	2.8	1.5					
Avg (µg/m <sup>3</sup> )	18.5	14.7	13.2					
STDEV (µg/m <sup>3</sup> )	15.6	10.5	10.2					
COV (%)	84.3	71.3	77.0					

**Table 7-31 San Joaquin Valley rural/interbasin PM<sub>2.5</sub> carbonaceous aerosols concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )			Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SNFH	FEL	FELF					
12/14/99	12.8	4.1		12.8	4.1	8.4	6.2	73.1
12/20/99	19.3	11.0	10.7	19.3	10.7	13.6	4.9	36.1
12/26/99	16.9	7.1	5.9	16.9	5.9	10.0	6.0	60.4
1/1/00	13.3		2.8	13.3	2.8	8.1	7.4	91.5
Max (µg/m <sup>3</sup> )	19.3	11.0	10.7					
Min (µg/m <sup>3</sup> )	12.8	4.1	2.8					
Avg (µg/m <sup>3</sup> )	15.6	7.4	6.5					
STDEV (µg/m <sup>3</sup> )	3.1	3.5	3.9					
COV (%)	20.0	46.7	60.8					

**Table 7-32 San Joaquin Valley rural/interbasin PM<sub>2.5</sub> ammonium sulfate concentrations during the December 1999 episode.**

Date	Concentrations (µg/m <sup>3</sup> )			Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SNFH	FEL	FELF					
12/14/99	1.1	1.2		1.2	1.1	1.2	0.1	8.5
12/20/99	2.0	2.1	2.4	2.4	2.0	2.2	0.2	8.7
12/26/99	0.6	1.8	1.7	1.8	0.6	1.4	0.7	48.3
1/1/00	2.6		1.9	2.6	1.9	2.3	0.5	20.3
Max (µg/m <sup>3</sup> )	2.6	2.1	2.4					
Min (µg/m <sup>3</sup> )	0.6	1.2	1.7					
Avg (µg/m <sup>3</sup> )	1.6	1.7	2.0					
STDEV (µg/m <sup>3</sup> )	0.9	0.5	0.3					
COV (%)	56.3	26.4	17.3					

**Table 7-33 San Joaquin Valley rural/interbasin PM<sub>2.5</sub> ammonium nitrate concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )			Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SNFH	FEL	FELF					
12/18/00	2.1	10.1	10.6	10.6	2.1	7.6	4.7	62.2
12/20/00	6.6	12.8	13.3	13.3	6.6	10.9	3.7	34.3
12/25/00		11.7	13.9	13.9	11.7	12.8	1.6	12.6
12/26/00	1.2	12.3	13.9	13.9	1.2	9.1	6.9	75.5
12/27/00	3.0	14.8	12.7	14.8	3.0	10.1	6.3	62.1
12/28/00	10.3	25.8	24.7	25.8	10.3	20.2	8.7	42.8
1/1/01	15.5	26.1	41.8	41.8	15.5	27.8	13.2	47.6
1/4/01	12.1	52.4	50.3	52.4	12.1	38.3	22.7	59.2
1/5/01	18.3	62.1	64.6	64.6	18.3	48.3	26.1	53.9
1/6/01	9.4	29.6	18.4	29.6	9.4	19.1	10.1	52.8
1/7/01	3.5	20.8	11.4	20.8	3.5	11.9	8.7	72.6
Max (µg/m <sup>3</sup> )	18.3	62.1	64.6					
Min (µg/m <sup>3</sup> )	1.2	10.1	10.6					
Avg (µg/m <sup>3</sup> )	8.2	25.3	25.0					
STDEV (µg/m <sup>3</sup> )	5.9	17.3	18.6					
COV (%)	71.8	68.3	74.3					

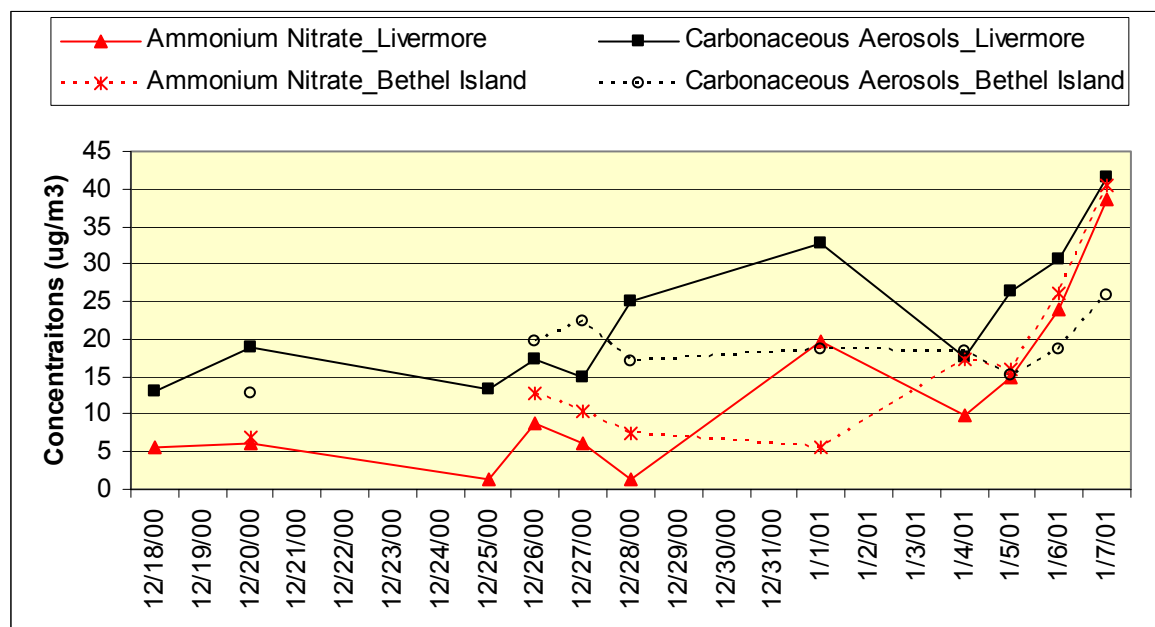
**Table 7-34 San Joaquin Valley rural/interbasin PM<sub>2.5</sub> carbonaceous aerosols concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )			Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SNFH	FEL	FELF					
12/18/00	7.1	4.7	4.3	7.1	4.3	5.4	1.5	27.8
12/20/00	8.3	6.1	7.1	8.3	6.1	7.2	1.1	15.4
12/25/00		3.5	5.5	5.5	3.5	4.5	1.4	31.2
12/26/00	8.1	4.8	3.5	8.1	3.5	5.5	2.4	43.7
12/27/00	7.5	6.7	4.6	7.5	4.6	6.3	1.5	23.9
12/28/00	10.2	7.6	7.9	10.2	7.6	8.6	1.4	16.3
1/1/01	12.6	4.8	6.9	12.6	4.8	8.1	4.1	50.2
1/4/01	9.9	13.2	10.2	13.2	9.9	11.1	1.9	16.7
1/5/01	14.9	12.6	13.5	14.9	12.6	13.7	1.2	8.5
1/6/01	8.9	8.2	8.2	8.9	8.2	8.5	0.4	4.9
1/7/01	7.6	7.5	4.9	7.6	4.9	6.7	1.5	22.8
Max (µg/m <sup>3</sup> )	14.9	13.2	13.5					
Min (µg/m <sup>3</sup> )	7.1	3.5	3.5					
Avg (µg/m <sup>3</sup> )	9.5	7.2	7.0					
STDEV (µg/m <sup>3</sup> )	2.5	3.2	2.9					
COV (%)	26.4	43.6	42.3					

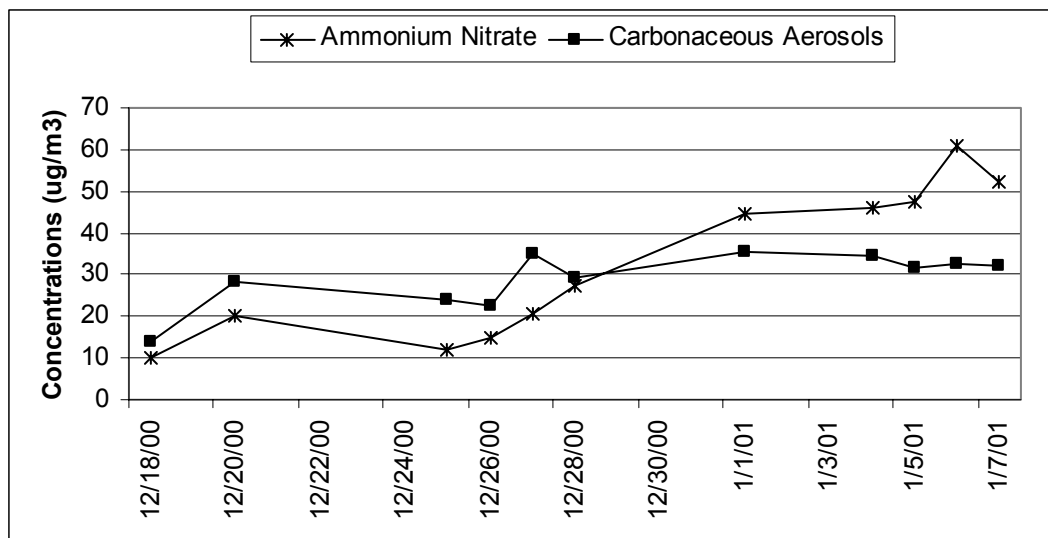
**Table 7-35 San Joaquin Valley rural/interbasin PM<sub>2.5</sub> ammonium sulfate concentrations during the December 2000 episode.**

Date	Concentrations (µg/m <sup>3</sup> )			Max (µg/m <sup>3</sup> )	Min (µg/m <sup>3</sup> )	Avg (µg/m <sup>3</sup> )	STDEV (µg/m <sup>3</sup> )	COV (%)
	SNFH	FEL	FELF					
12/18/00	0.9	2.5	2.6	2.6	0.9	2.0	0.9	47.1
12/20/00	0.9	1.8	2.0	2.0	0.9	1.6	0.6	38.3
12/25/00		2.2	2.9	2.9	2.2	2.6	0.5	18.0
12/26/00	0.8	2.3	2.5	2.5	0.8	1.9	0.9	48.8
12/27/00	0.7	2.4	2.3	2.4	0.7	1.8	1.0	51.9
12/28/00	1.1	3.0	2.9	3.0	1.1	2.4	1.1	44.7
1/1/01	1.8	2.5	4.1	4.1	1.8	2.8	1.2	41.9
1/4/01	1.3	4.7	4.4	4.7	1.3	3.5	1.9	55.4
1/5/01	1.5	4.8	5.4	5.4	1.5	3.9	2.1	54.6
1/6/01	0.9	2.9	2.1	2.9	0.9	2.0	1.0	49.1
1/7/01	0.7	1.9	1.4	1.9	0.7	1.3	0.6	45.7
Max (µg/m <sup>3</sup> )	1.8	4.8	5.4					
Min (µg/m <sup>3</sup> )	0.7	1.8	1.4					
Avg (µg/m <sup>3</sup> )	1.1	2.8	3.0					
STDEV (µg/m <sup>3</sup> )	0.4	1.0	1.2					
COV (%)	33.8	36.6	39.3					

**Figure 7-9 Ammonium nitrate and carbonaceous aerosols concentrations at Livermore and Bethel Island during the December 2000 episode.**



**Figure 7-10 Average PM<sub>2.5</sub> concentrations of ammonium nitrate and carbonaceous aerosols across the eight urban sites in the San Joaquin Valley during the December 2000 episode.**



## 8 CONCLUSIONS

PM concentrations in central California exhibit a strong seasonal pattern with high concentrations in fall and winter and low concentrations in spring and summer. The 15 months of CRPAQS monitoring included two winters (1999/2000 and 2000/2001) and one fall (2000). The spring and summer CRPAQS concentrations were as low as was expected based on the historic data. The winter PM<sub>2.5</sub> concentrations far exceeded historic levels but the PM<sub>10</sub> concentrations, despite conducive meteorology, never reached historic peaks. Several factors may have contributed to the difference between PM<sub>10</sub> and PM<sub>2.5</sub> levels. First of all, the control measures implemented over the years have helped to reduce the fugitive dust portion of PM<sub>10</sub>. Another possible explanation is that in the past the PM<sub>2.5</sub> monitoring network was not as dense and the sampling schedule not as intense as PM<sub>10</sub>. Therefore, the historic network may not have accurately estimated the magnitude of the PM<sub>2.5</sub> problem. Third, the weather during the CRPAQS winter periods may have been unusually conducive to PM<sub>2.5</sub> formation and accumulation.

Fall CRPAQS concentrations were lower compared to previous years and there were no significant fugitive dust driven events. The PM<sub>2.5</sub> concentrations were highest during winter months (January, February, November, and December). However, even during those months concentrations varied significantly due to the episodic nature of the PM<sub>2.5</sub> problem in the San Joaquin Valley. They were high when stagnant conditions, with strong inversions, low mixing heights, and light and variable winds, persisted in the Valley for a number of days. Low concentrations were measured when vertical and horizontal mixing was good or when it was raining. The PM<sub>10</sub> concentrations were highest during fall and winter (January and September through December). Fall PM<sub>10</sub> concentrations were less variable compared to winter.

The CRPAQS network, with more sites and more frequent sampling to draw on, captured higher concentrations than the routine network. It not only measured higher peaks during prolonged winter episodes, but also captured a short-term high wind event that was missed by the less frequent sampling of the routine network. Some source-oriented CRPAQS sites measured concentrations higher than population-oriented routine sites.

PM<sub>10</sub> as well as PM<sub>2.5</sub> concentrations were lower in the northern San Joaquin Valley than in the central and southern. The three highest PM<sub>2.5</sub> urban sites, Bakersfield, Fresno, and Visalia, had similar average concentrations of about 30 µg/m<sup>3</sup> and peak concentrations of 155 µg/m<sup>3</sup>, 148 µg/m<sup>3</sup>, and 130 µg/m<sup>3</sup>, respectively. The highest rural site, Pixley, had a slightly lower average (28 µg/m<sup>3</sup>) and a higher peak (165 µg/m<sup>3</sup>) compared to the highest urban site. Rural sites on the Valley outskirts had the lowest concentrations. Urban sites in the San Francisco Bay Area and Sacramento Valley had average PM<sub>2.5</sub> concentrations almost 50% lower than urban San Joaquin Valley sites. Another significant difference between the basins was that the high PM<sub>2.5</sub> sites in the San Joaquin Valley also had high PM<sub>10</sub> concentrations. This was not the case in the San Francisco Bay Area and Sacramento Valley air basins where locations of high PM<sub>2.5</sub> sites were different from high PM<sub>10</sub> sites.

The main chemical components of the PM mass were ammonium nitrate, carbonaceous aerosols, and geological material. The geological material was only a significant component of PM<sub>10</sub> but not PM<sub>2.5</sub>. Both ammonium nitrate and carbonaceous aerosols were higher during the winter than during the rest of the year. The average PM<sub>2.5</sub> ammonium nitrate concentrations during the four winter months was  $20.2 \pm 18.7$  µg/m<sup>3</sup> while during the remaining eight months, the average was only  $2.7 \pm 2.8$  µg/m<sup>3</sup>. Similar, but less pronounced, differences were also observed for carbonaceous aerosols. PM<sub>2.5</sub> carbonaceous aerosols winter concentrations were  $16.0 \pm 13.4$  µg/m<sup>3</sup> while the average for the remaining eight months was  $8.5 \pm 3.8$  µg/m<sup>3</sup>. In the San Joaquin Valley, monthly average concentrations of carbonaceous aerosols were about 20% lower than ammonium nitrate during winter but three times higher the rest of the year. In the San Francisco Bay Area and the Sacramento Valley, carbonaceous aerosols concentrations were consistently higher than ammonium nitrate across the year. Concentrations of geological material had a unique seasonal pattern; they dominated the PM mass for most of the year (from April through October) but were highest in fall. Ammonium nitrate was mostly found in the PM<sub>2.5</sub> fraction, as indicated by similar concentrations found in the PM<sub>10</sub> and PM<sub>2.5</sub> size fractions. Carbonaceous aerosols were also predominantly found in the fine fraction for most of the year, but during September and October over 60% of carbonaceous aerosols were in the coarse fraction. The significant presence of coarse carbonaceous aerosols in the fall may suggest that geological material, which also peaks during this time of the year, is a source of coarse carbon.

Ammonium nitrate and carbonaceous aerosols comprised over 80% of PM<sub>2.5</sub> mass. Throughout the course of the study each component had a wide range of concentrations. Ammonium nitrate in the San Joaquin Valley ranged from 1 to 108 µg/m<sup>3</sup> while carbonaceous aerosols from 1 to 92 µg/m<sup>3</sup>. The average PM<sub>2.5</sub> mass for the entire duration

of the study was dominated by carbonaceous aerosols at urban sites and by ammonium nitrate at rural sites. During an episode, ammonium nitrate was a leading component at all urban and rural sites, except Fresno where carbonaceous aerosols dominated the PM<sub>2.5</sub> mass. Ammonium nitrate and carbonaceous aerosols had very different spatial and temporal patterns. Ammonium nitrate concentration exhibited a very distinctive buildup pattern. Concentrations were highly variable temporally but fairly uniform spatially, especially towards the end of the episode. Carbonaceous aerosols had a much less pronounced buildup pattern. Concentrations were less variable temporally but more variable spatially. The spatial differences always followed the same pattern. Carbonaceous aerosols concentrations were always highest at Fresno. The other urban sites were significantly lower and rural/intrabasin sites were yet lower. Rural/interbasin sites had the lowest carbonaceous aerosols concentrations.

PM<sub>10</sub> mass was on average dominated by geological material, followed by carbonaceous aerosols and ammonium nitrate. Majority of geological material was in the coarse size fraction. The average ratio of PM<sub>2.5</sub>/PM<sub>10</sub> geological material was 0.07. Both size fractions had similar seasonal patterns; lowest during winter and highest from April through October, but the range of monthly average concentrations was significantly different; 0.4 µg/m<sup>3</sup> to 1.8 µg/m<sup>3</sup> for the PM<sub>2.5</sub> fraction and 6 µg/m<sup>3</sup> to 30.6 µg/m<sup>3</sup> for the PM<sub>10</sub> fraction. . PM<sub>10</sub> ammonium nitrate and carbonaceous aerosol patterns were similar to those of PM<sub>2.5</sub>. .

The site-to-site and day-to-day variability was further examined using the data for the two most severe episodes, December 1999 and December 2000. Each episode had it's own characteristics, but some general conclusions can be drawn based on their comparison. During an episode each site experienced significant variability in concentrations. At the beginning of the episode concentrations were low but increased every day due to the accumulation of primary pollutants and formation of secondary pollutants. Concentrations at some sites were more variable than at others. For example, urban concentrations were generally less variable than rural because rural sites were more influenced by transport and large scale meteorology and less by local sources compared to urban sites. Rural sites located on the outskirts of the Valley, rural/interbasin sites, had even more variability than rural sites more centrally located. Depending on the transport directions some peripherally located sites, but usually not all, experienced increases in concentrations during an episode. Therefore, if these sites were analyzed as a group, they had a huge variability in concentrations.

Location within the Valley also impacted data variability. Monitoring sites in the northern and southern San Joaquin Valley were less impacted by transport compared to more centrally located sites like Fresno. Transport in either direction, southern or northern, usually affected the central Valley to some degree, while northern and southern locations might not have been affected. Therefore, Fresno had the least variable data of all sites.

The day-to-day variations changed during the course of the episode. At the beginning, the data were more variable. Towards the end of the episode, as meteorology became more uniform and transport started to play a larger role, concentrations became more uniform.

A particulate matter episode involved a buildup of concentrations usually driven by a large scale meteorology. Concentrations increased almost every day, with some small variations, until they reached a peak. Elevated concentrations continued until there was a change in meteorology significant enough to bring concentrations down. Urban monitoring sites experienced a more rapid buildup in concentrations compared to rural sites due to the proximity of emission sources.